PATENT ABSTRACTS OF JAPAN

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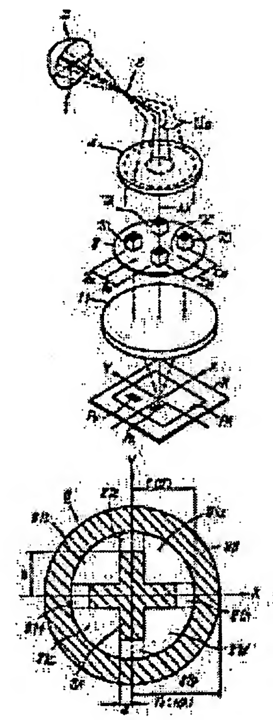
(54) PROJECTION ALIGNER

(57)Abstract:
PURPOSE: To prevent the image-formation performance with reference to an inclined pattern, especially the improvement degree of the depth of focus, of an aligner from being deteriorated by a method wherein, although many optimized parts are included in longitudinal and transverse patterns on a reticle as the light-source shape of a deformed light source, some optimum parts are also included in the inclined pattern.
CONSTITUTION: The shape of a light-shielding plate 8 includes a surface light-source part which is effective in forming the image of slightly inclined patterns Ta, Tb, and the greater part of a central crossed light-shielding part shields a surface light-source part which is not suitable for not only a longitudinal pattern Pv and a groove pattern Pb but also the inclined patterns Ta, Tb. As a result, when the image of the inclined patterns Ta, Tb is formed, a resolution and a depth of focus which are remarkably higher than those by an ordinary illumination (a simply circular or polygonal surface light source using an optical axis AX as the center) in conventional cases can be obtained. Consequently, it is possible to prevent the image-formation performance with reference to the inclined patterns, especially the improvement degree of the depth of focus, of the aligner from being deteriorated.



CLAIMS

[Claim(s)]
[Claim 1]An illumination system which illuminates a mask in which a pattern which should be projected was formed.
A projection optical system which projects an image of said pattern on a sensitized substrate.
Are the above the projection aligner which it had and said illumination system, An illumination-light study system which has a field which serves as a relation of the Fourier transform optically to a pattern surface side of said mask inside, While; this light distribution setting-out means distributes said illumination light including a light distribution setting-out means to distribute illumination light in a predetermined radius centering on an optic axis on said Fourier transformation plane or its nearby surface, in a field of the shape of zona orbicularis of specified width centering on said optic axis, Said illumination light is distributed over a field for two or more discrete copies except the central part inside a field of the shape of this zona orbicularis.

[Claim 2]A light source for irradiating with illumination light a mask in which a pattern which should be projected was formed.
An illumination-light study system from which a field which serves as a relation of the Fourier transform optically to a pattern surface side of said mask is formed in an inside, and a secondary light source of said light source is made by this Fourier transformation plane or its nearby surface, A projection optical system which enters light from a pattern of said mask irradiated by illumination light from this illumination-light study system, and carries out image formation projection of the image of this pattern on a sensitized substrate.
The 1st pattern shape that has periodicity in each of a 2-way with which are the projection aligner provided with the above and a 2-way and a pattern on said mask cross at right angles mutually, When there are more rates that it is formed with the 2nd pattern shape that has periodicity in the direction which intersects each of this 2-way, and said 1st pattern shape closes on said mask than a rate that said 2nd pattern shape closes, So that oblique illumination light corresponding to the direction of the periodicity of form of said 1st pattern may be made, The 1st setting-out component which sets the 1st surface of light source as each of four fields which carries out eccentricity only of the specified quantity and is mutually located symmetrically from an optic axis of said illumination-light study system on said Fourier transformation plane or its nearby surface, So that oblique illumination light corresponding to the direction of the periodicity of said 2nd pattern shape may be made, It had the 2nd setting-out component which sets the 2nd surface of light source as each of four fields which carries out eccentricity only of the specified quantity and is mutually located symmetrically from an optic axis of said illumination-light study system on said Fourier transformation plane or its nearby surface, and area of said 1st surface of light source was made larger than area of said 2nd surface of light source.

[Claim 3]Equipment given in the 2nd clause of a claim specifying said 1st setting-out component and the 2nd setting-out component with transparent part form of a gobo arranged in a Fourier transformation plane of said illumination-light study system, or its nearby surface.
[Claim 4]Equipment given in the 3rd clause of a claim, wherein said illumination-light study system has arranged said gobo to the projection surface side of this fly eye lens including a fly eye lens which makes said surface of light source.
[Claim 5]The 1st pattern shape formed in a 2-way which intersects perpendicularly on a mask with periodicity, A projection optical system which carries out image formation projection of the 2nd pattern shape that has periodicity in the other direction on a sensitized substrate, While making the image formation of the light source image by fly eye lens which forms a light source image of a size which enters light from a light source and is included by circular area of a predetermined radius, and this fly eye lens carry out in the center of a pupil surface of said projection optical system, or its nearby surface, In a projection aligner provided with a condensing optical system on which light from each point within said light source image is made to superimpose on said mask, When two axes of coordinates corresponding to each of a 2-way which intersects perpendicularly mutually among the directions of the periodicity of said pattern by making the center of said light source image into the starting point are set up, The 1st transparent part that four quadrants specified with this 2 ** axis of coordinates were alike, respectively, and was mostly formed with an identical area, From said starting point, in an equidistant position mostly to each four on said two axes of coordinates. A projection aligner having arranged a gobo which has the 2nd transparent part mostly formed with an identical area to the injection side of said fly eye lens, and changing area of the 1st transparent part of said gobo, and the 2nd transparent part according to importance of said 1st pattern shape and the 2nd pattern shape.
[Claim 6]A projection optical system which carries out image formation projection of the pattern of a mask on a sensitized substrate.
An illumination-light study system which enters light from a light source, forms the surface light source of prescribed shape in an optical Fourier transformation plane to said mask, or its nearby surface, and irradiates with light from this surface light source uniformly on said mask.
When r and a coherence factor of said surface light source are made into a sigma value for a radius of a circle which is the projection aligner provided with the above, defined the rectangular coordinate system XY by having made the center of said surface light source into the starting point, and was approximated to an outside of said surface light source, It is each about the coefficients a and b. 0.1 r/sigma<=a <= 0.4 r/sigma As 0.4 r/sigma<=b <= 0.8 r/sigma, A light-intensity-distribution adjusting member which makes light intensity with inside of a field of -a<=X<=a, the inside of a field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or is set to about 0 was provided.

[Claim 7]Equipment given in the 6th clause of a claim when the coefficient c is made into 0.3 r/sigma<=c <= 0.6 r/sigma, wherein said light-intensity-distribution adjusting member makes light intensity in a field of $X^2+Y^2<=c^2$ smaller than other fields or sets it to about 0 on said surface light source.
[Claim 8]When said illumination-light study system is constituted so that image formation of the starting point of said surface light source may be carried out to the center of a pupil surface of said projection optical system, and a radius on said surface light source of an effectual pupil diameter of this projection optical system is made into r_0. Equipment given in any 1 clause of the 6th clause of a claim or the 7th clause making or more into 0.7 a sigma value which is ratio r/r_0 with the radius r of said surface light source

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[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application]This invention relates to the exposure device which devised to the lighting of the mask (reticle) in which the pattern which should be transferred especially was formed about the projection aligner used for the exposure transfer of minute patterns, such as Integrated Circuit Sub-Division and a liquid crystal display element.
[0002]
[Description of the Prior Art]In the lithography process which a miniaturization follows every year, introduction of the practical projection aligner for 64 MD-RAM manufacture is indispensable now. In order to attain projection exposure transfer of such a detailed pattern in sufficient accuracy, more various devices than before are proposed. The pattern which should be transferred especially like a line and space (it is considered as L&S below) before long, when it had periodicity in a certain direction, super resolution technology, such as JP,H4-108612,A and JP,H4-225514,A, was proposed as a technique which resemble markedly and to which resolution and the depth of focus are made to expand rather than before.
[0003]This super resolution technology is making special only the orientation characteristic of the illumination light to the mask substrate (reticle) in which the L&S pattern which should be carried out projection exposure was formed, and makes the detailed pattern which was not resolved resolve with sufficient depth of focus in the conventional lighting. The orientation characteristic of the illumination light is made by controlling distribution of the illumination luminous flux within the Fourier transformation plane to the reticle in an illumination-light study system, i.e., distribution of secondary light source images, corresponding to the degrees of detail of the pattern of L&S of a reticle (pitch etc.).
[0004]Drawing 1 is a perspective view showing the typical composition of an illumination-light study system which applied the technology indicated by the above-mentioned gazette. Here, the emission point of this mercury lamp 1 is arranged to the 1st focus of the elliptic mirror 2, using the mercury lamp 1 as an illumination light source. Once converging the illumination light ILa reflected with the elliptic mirror 2 with the 2nd focus 3, it is reflected by an unillustrated mirror and it enters into the collimating lens system 4. When the elliptic mirror 2 and the mercury lamp 1 are generally combined like drawing 1, the section of the illumination light ILa has zona-orbicularis-like (doughnut shape) intensity distribution. The illumination light ILa of the section of the shape of this zona orbicularis is mostly changed into a parallel pencil by the collimating lens system 4, and reaches the gobo 8 arranged at the Fourier transformation plane within an illumination system. On the gobo 8, four openings are provided from the optic axis AX at an equidistant position, and the fly eye lenses 7A, 7B, 7C, and 7D are formed in each of this opening. Each of each entrance plane of these fly eye lenses 7A-7D is located in the illumination luminous flux ILa of a zona-orbicularis-like section. The point light source image of the mercury lamp 1 is formed in each injection side of the fly eye lenses 7A-7D only several minutes of the element lens in the fly eye lens. Therefore, secondary light source images (surface light source) are formed in each projection surface of the fly eye lenses 7A-7D.
[0005]The illumination light from each of each fly eye lenses 7A-7D is uniformly superimposed on pattern formation field PA of the reticle R, and it is irradiated with it by the inverse Fourier transform optical system 11 (it is henceforth called a condenser lens for convenience) containing a condenser lens etc. When the reticle R is arranged and the center is made into the starting point of the coordinate system XY so that the optic axis AX may pass at the center of pattern space PA of the reticle R, a L&S-like reticle pattern, In many cases, it is divided into the L&S pattern (vertical pattern) Pv which has a pitch in the direction of X, and the L&S pattern (horizontal pattern) Ph which has a pitch in the direction of Y. That is, in pattern space PA, a pattern group with periodicity is gathered and formed about the 2-way of the direction of X, and the direction of Y.
[0006]If Lighting Sub-Division conditions shall be optimized to the minimum thing among the L&S pattern Pv, X of Ph, and the pitch of the direction of Y, eccentricity yalpha from each optic axis AX of the fly eye lenses 7A-7D and xbeta will be decided by the minimum pitch of the L&S pattern, and the most important relation. The wavelength of Gy (micrometer) and the illumination light ILa for the minimum pitch of the direction of Y of the L&S pattern Ph For example, lambda (micrometer), When the angle of diffraction (angle from a zero order light) of the primary diffracted light which sets the distance from the condenser lens 11 to the reticle R, i.e., a focal distance, to f (mm), and is generated from the L&S pattern Ph is set to 2thetay (rad), Eccentricity yalpha of the direction of Y of one fly eye lens to which its attention is paid is decided that sin2theta y=lambda/Gy and y alpha=f-sin theta y are filled almost simultaneous.
[0007]When the angle of diffraction of the primary diffracted light which sets the minimum pitch of the direction of X of the L&S pattern Pv to Gx (micrometer), and is generated from the L&S pattern Pv is set to 2thetax (rad), It is decided that sin2theta x=lambda/Gx and x beta=fsin theta x satisfy eccentricity xbeta of the direction of X of one fly eye lens to which its attention is paid almost simultaneous. As mentioned above, in the conventional special illumination (modification light source). For super resolution projection of the pattern Pv which has a pitch in the direction of X among the L&S patterns on the reticle R. the pair (the fly eye lenses 7A and 7D.) of secondary light source images which carried out eccentricity in the direction of X symmetrically on the Fourier transformation plane Or for super resolution projection of the pattern Ph which the oblique illumination light from the fly eye lenses 7B and 7C contributes, and has a pitch in the direction of Y. The oblique illumination light from the pair (the fly eye lenses 7A and 7B

or fly eye lenses 7C and 7D) of secondary light source images which carried out eccentricity in the direction of Y symmetrically on the Fourier transformation plane contributes.
[0008]The rotary shutter etc. which control a start and discontinuation of exposure to the 2nd focus 3 in drawing 1 are arranged. The 2nd focus 3 is secondary light source images and conjugate which are formed in each projection surface side of the fly eye lenses 7A-7D, and each entrance plane of the fly eye lenses 7A-7D has a pattern surface side of the reticle R, and conjugate.
[0009]
[Problem to be solved by the invention]In the conventional technology like the above, it is effective in improving resolution and the depth of focus only about the period pattern of the specific direction of the circuit original edition (reticle) which should be transferred, for example, the 2-way which intersects perpendicularly. However, about the pattern which has periodicity in other directions, especially the direction rotated 45 degrees to each of the above-mentioned 2-way which intersects perpendicularly, there was a problem that resolution and the depth of focus fell rather than the exposure device which applied the usual illumination.
[0010]This invention raising substantially the resolution and the depth of focus of a 2-way pattern which accomplish in view of such a problem and have periodicity in each of the direction [parallel to especially a reticle outside] in every direction on a reticle. It aims at offer of the projection aligner with which high resolution and large focus depth are obtained from usual equipment also with the slanting (for example, 45-degree rotation) pattern in which a direction differs from these.
[0011]
[Means for solving problem]The two-dimensional form of the light source image (surface light source) formed in the Fourier transformation plane in the illumination-light study system for mask Lighting Sub-Division of a projection aligner is applied to the conventional form, and it was made to change it a little in this invention. The zona-orbicularis portion outside the circle C2 of a predetermined radius is kept from specifically shading at all from the starting point among the surface light sources (here projection surface of the fly eye lens 7) included in the almost circular field C1, as shown in drawing 2. And the cross shape shade part 8A prolonged in each of X and the direction of Y from the starting point is formed inside the circle C2, and the transparent part (surface of light source) mutually divided into each of four quadrants specified with X and a Y coordinate axis was formed. The transparent part of the four quadrants contributes to the super resolution of a cyclic pattern which has a pitch in each of X and the direction of Y as usual.
[0012]Although all of four points of the cross shape shade part 8A were installed in the former more than the radius (almost radius of the circle C1) of the surface light source, four points of the cross shape shade part 8 are made smaller than the radius of the surface light source, and it was made for the surface light source small in area to exist also in the outside of these four points in this invention. Setting out of the rectangular coordinate system XY in this drawing 2 is completely the same as the thing of drawing 1, and the starting point of the coordinate system XY is in agreement with the optic axis AX of an illumination-light study system or a projection optical system. In drawing 2, EP expresses the pupil surface of the projection optical system seen in the projection surface of the fly eye lens 7 as a two-dimensional light source image (surface light source).
[0013]Generally with this kind of projection aligner, a surface light source image (image of the projection surface of the fly eye lens 7) is formed in the pupil surface (Fourier transformation plane) of a projection optical system. And what is been radius r_0 of pupil EP of a projection optical system seen on the Fourier transformation plane in an illumination-light study system and ratio r/r_0, the radius r of the surface light source, is called a sigma value. Then, if 0.7 to about 0.8 and radius r' of the circle C2 are made into about $0.64r_0=0.64$ r/sigma for the radius of the circle C1 by the sigma value in drawing 2, The effect of super resolution fully comes to be acquired also to a period pattern with a line width of 0.4-0.45 micrometer which has a pitch in the direction rotated only 45 degrees to each of X and the direction of Y. About the circle C1, and the setups of C2 and the size conditions of the cross shape shade part 8A which were shown in drawing 2, it illustrates in detail in future embodiments.
[0014]
[Function]While many portions optimized by the pattern in every direction on a reticle were included as the so-called light source configuration of a modification light source, it was made to also include slightly the portion (outside at the tip of the cross shape shade part 8A of drawing 2) optimal also about a slanting pattern in this invention. For this reason, in the conventional modification light source, the resolution and the depth of focus of a slanting pattern which had usually got worse from Lighting Sub-Division rather are also usually improvable compared with Lighting Sub-Division. Since the balance of the area (light volume) of the light source part optimized by the pattern in every direction and the area (light volume) of the light source part optimized by the slanting pattern is also optimized, an improvement of the resolution at the time of projection of a pattern in every direction and the depth of focus can also be realized almost to the same extent as the case of the conventional modification light source configuration. When a zona-orbicularis-like surface light source part (radius r'-r) is provided in the outside of the cross shape shade part 8A like drawing 2, even if the direction of the periodicity of a slanting pattern is not necessarily 45 degrees (or 135 degrees) to each of X and the direction of Y, the effect of this invention is acquired.
[0015]
[Working example]Drawing 3 is a figure showing the overall outline composition of the projection aligner by the embodiment of this invention. And the same mark is given to the thing in drawing 1, and the thing of the same function by the component in drawing 3. The illumination light ILa from the mercury lamp 1 enters into the fly eye lens 7 via the collimating lens system 4, the mirror 5, and the input side field lens 6, after being converged by the 2nd focus 3 with the elliptic mirror 2. The rotary shutter 19A rotated in the position of the 2nd focus 3 in one way is arranged, and the shutter 19A is controlled by the drive units (a motor, a drive circuit, etc.) 19B. When the illumination light ILa enters into the fly eye lens 7, it has zona-orbicularis-like intensity distribution like the case of drawing 1, but in the case of that from which the form of the gobo (diaphragm) 8 provided in the injection side of the fly eye lens 7 makes a modification light source like drawing 2, it is suitable. However, when switching the gobo 8 to the gobo 9 with the same circular opening diaphragm as usual and usually illuminating, the intensity distribution of the shape of zona orbicularis of the illumination light ILa is not so preferred. In the case of that to which especially the reticle R applied the phase shift method, the numerical aperture of the illumination light to the reticle R is extracted to a comparatively small value (it is 0.2 to about 0.4 at a sigma value). In that case, only the light of the center section of the intensity distribution of the shape of zona orbicularis of the illumination light ILa from the element lens of the center portion of the fly eye lens 7, i.e., the illumination light, will be used for reticle Lighting

Sub-Division, and will cause an illumination fall.
[0016]then, the time of usually changing to Lighting Sub-Division — for example — — it is good to arrange the prism 30 which is indicated by USP. 4,637,691 etc. exchangeable between the collimating lens 4 and the field lens 6, and to operate the intensity distribution of the shape of zona orbicularis of the illumination light ILa orthopedically to distribution of a circle configuration. Now, the turret 10 which holds the gobo 8 and the gobo 9 usually for light sources for modification light sources like drawing 2 exchangeable is formed in the injection side of the fly eye lens 7. With the drive unit 10A, the turret 10 is rotated at a given predetermined angle. In drawing 3, the gobo 8 is positioned at the injection side of the fly eye lens 7. In this way, the illumination light ILb which passed along the transparent part of the gobo 8 enters into the condenser lens 11 via the output side field lens 13 and the mirror 12. With the condenser lens 11, the light from each point light source of two or more selected element lenses in the fly eye lens 7 is altogether superimposed on the pattern space of the reticle R, and is irradiated uniformly. The illumination light ILa shown in drawing 3 is expressed on behalf of the light from the point light source of one selected element lens.
[0017]Here, the relation between the shade part form of the gobo 8 and element lens arrangement of the fly eye lens 7 is the same as what was shown in drawing 2, also makes a shade part actually the outside of the circle C1 in drawing 2, and vapor-deposits and makes a metal layer etc. on transparent plates, such as a quartz plate, also including the cross shape shade part 8A. The projection surface (or field of the gobo 8) of the fly eye lens 7 has a relation of the optical Fourier transform to the pattern surface side of the reticle R. Therefore, with the condenser lens 11, the light from the point light source made from one element lens of the fly eye lens 7 serves as a parallel pencil of the incidence angle theta, and carries out oblique illumination of the reticle R. At this time, the eccentricity (distance from the optic axis AX) on one Fourier transformation plane of the point light source is in the sine (sin theta) and proportionality of the incidence angle theta. As for this incidence angle theta, an optimum dose value exists according to the pitch of the periodic pattern on the reticle R. Since it is indicated by previous JP,H4-225514,A etc. about the deciding method of X, eccentricity yalpha to a pattern periodic to each of the direction of Y, and xbeta, the explanation is omitted here.
[0018]zero-order diffracted-light D_0among each diffracted light generated from period pattern of specific pitch on reticle R by the exposure of illumination light ILb , and one primary diffracted-light D_1 — a both-sides call — the wafer W is reached after being symmetrically distributed within pupil EP of centric projection optical system PL. Therefore, image formation of the period pattern of the specific pitch on the reticle R is carried out on the wafer W as a light-and-darkness image made by one interference with primary diffracted-light D_1 and zero-order diffracted-light D_0. Since the regist layer is applied to the surface of the wafer W, the opened times of the shutter 19A are controlled, and if the amount of optimal exposing light corresponding to the resist is given, the reduced image of the period pattern of the reticle R will be formed in a regist layer.
[0019]The wafer W is laid on the stage WST which carries out two-dimensional movement in a field vertical to the optic axis AX, and the stage WST is driven with the drive units 18B, such as a motor, based on the measuring result of the coordinates position by the laser interferometer 18A. The control unit 20 controls the wafer stage WST, the drive unit 19B for shutters, and the drive unit 10A for turrets in generalization. Automatic Control Division according to the library-name of the reticle R to the drive unit 10A for turrets or the manual control by the directions from an operator is especially possible.
[0020]Drawing 4 is a top view showing the concrete form of the gobo 8 by the 1st embodiment, and drawing 5 shows typically the period pattern arrangement on the reticle R when it sees by the same coordinate system as the coordinate system XY in drawing 4. As shown in drawing 5, on the reticle R The direction X of outside each neighborhood of a reticle. If many periodic vertical patterns Pv (a pitch is the direction of X) parallel to Y and horizontal patterns Ph (a pitch is the direction of Y) exist and carry out comparatively compared with them, it is small, but the periodic slanting patterns Ta and Tb which carried out 45-degree (or 135 degrees) rotation to each of X and the direction of Y exist. The composition of such a pattern is common not only in this example but in the reticle as the circuit original edition for semiconductor devices.
There are many rates of the vertical pattern Pv and the horizontal pattern Ph, and few things of the rate of the slanting patterns Ta and Tb are common.

[0021]If it irradiates with the illumination light from the illumination-light study system which applied the gobo 8 shown in drawing 4 to the reticle R which has these patterns, The resolution and the depth of focus at the time of projection with the vertical pattern Pv on the reticle R and the horizontal pattern Ph improve as usual by making into the surface light source each of the four flabellate area pellucida 81a, 81b, 81c, and 81d divided by the cross shape shade part 8A of the width 2a and length 2b. Here, the gobo 8 has outside diameter value r_0 and the zona-orbicularis shade part 8B of the inside diameter r in an outermost periphery, and length b from the starting point (point along which the optic axis AX passes) to the tip of the cross shape shade part 8A is set as the relation of r>b. If the inside diameter edge of the zona-orbicularis shade part 8B shall be equivalent to the circle C1 in drawing 2 and outside diameter value r_0 of the zona-orbicularis shade part 8B shall correspond to the effectual overall diameter (namely, maximum-mandibular-movements severalN.A.) of pupil EP of projection optical system PL, the ratio of the inside diameter value r of the zona-orbicularis shade part 8B, and outside diameter value r_0 — r/r_0 is exactly a sigma value of a coherence factor.
[0022]In the gobo 8 of drawing 4, the area pellucida 81e, 81f, 81g, and 81h effective in the image formation of the slanting patterns Ta and Tb is formed in each point of X of the cross shape shade part 8A, and the direction of Y. In this conventional kind of lighting, those four area pellucida 81e, 81f, 81g, and 81h was altogether made into the shade part. When a light source image (surface light source) is made to each of these four area pellucida 81e-81h, the side effects that some resolution and depths of focus at the time of projection of the vertical pattern Pv or the horizontal pattern Ph are degraded occur. However, since each area (or light volume) of the four area pellucida 81e-81h is small enough compared with each effective flabellate area pellucida [81a-81d] area (or light volume) to the vertical pattern Pv and the horizontal pattern Ph, Projection performance about the vertical pattern Pv or the horizontal pattern Ph is not spoiled greatly.
[0023]It is provided in the relation of each value r (sigma), a, and b of the gobo 8, 0.1 r/sigma<=a <= 0.4 r/sigma, and about 0.4 r/sigma<=b <= 0.8 r/sigma here. If the value a becomes smaller than 0.1 r/sigma (namely, $0.1r_0$), the effect as a modification light source will disappear and it will not usually be different from Lighting Sub-Division (a mere round shape or the polygon surface light source centering on the optic axis AX) at all. Since it will be made in the place which the center-of-gravity point on each four

flabellate area pellucida [81a-81d] area separated from the starting point of the gobo 8 greatly if the value a becomes larger than 0.4 r/sigma (namely, $0.4r_0$). Although optimization of the angle of inclination of the illumination light is achieved to the pattern Pv on the reticle R, and the thing to which the pitch became more detailed among Ph(s), optimization is not achieved to the pattern in which the pitch became coarse rather than it, but the expansion effect of the depth of focus becomes is hard to be acquired.

[0024]Since the unsuitable surface light source, i.e., area pellucida [81e-81h] area, will increase to resolving of the vertical pattern Pv and the horizontal pattern Ph if smaller also about the value b than 0.4 r/sigma, the pattern Pv in every direction and the depth of focus at the time of projection of Ph will decrease remarkably. Conversely, if the value b becomes larger than 0.8 r/sigma, the improvement effect of the resolution at the time of projection of the slanting patterns Ta and Tb or the depth of focus will diminish.

[0025]Though small, in the form of the gobo 8 shown in drawing 4 Slanting pattern Ta, The surface light source part effective in the image formation of Tb is included, and most central cross shape shade parts 8A are also shading the unsuitable surface light source part also not only to the vertical pattern Pv and the horizontal pattern Ph but to the slanting patterns Ta and Tb. for this reason, also in the image formation of the slanting patterns Ta and Tb, rather than conventional usual Lighting Sub-Division (it centers on the optic axis AX — being mere -- circular or the polygon surface light source), it can be markedly alike and high resolution and depth of focus can be obtained.

[0026]Now, drawing 6 shows the form by the 2nd embodiment of the gobo 8, and has attached the same mark to the same portion as the composition of the gobo 8 of drawing 4. Although this example is fundamentally the same as the gobo of drawing 4, it differs in that the circular shade part of radius r_c (r_c>a) was provided in the center of central cross shape shade part 8A'. When the central part of the surface light source is covered by a circular shade part, thus, the vertical pattern Pv, About the image formation of the horizontal pattern Ph, especially, it becomes less than the case where each area of the effective light source part 81a-81d, i.e., four flabellate area pellucida, is drawing 4, and the rate of each area of the effective light source part 81e-81h, i.e., four area pellucida, increases about the image formation of the slanting patterns Ta and Tb relatively. For this reason, the resolution and the depth of focus at the time of the image formation of the slanting patterns Ta and Tb are further improvable rather than the case of drawing 4.

[0027]The portion newly shaded with the gobo 8 of drawing 6 is a position near the optic axis AX in comparison.
Although it is effective in improving the depth of focus at the time of the image formation of the vertical pattern Pv of a pitch [that it is slightly coarse (the line width for example, on a wafer is 0.5 micrometers or more)], and the horizontal pattern Ph, there are not much length of a more detailed pitch, the horizontal pattern Pv, and an effect of improving resolution and the depth of focus to Ph.
Therefore, the L&S pattern on the reticle R which should be carried out projection exposure is restricted to the thing of the comparatively detailed pitch, And though it is also small the comparable slanting pattern of the pitch, when it is contained at a moderate rate, the length and the horizontal pattern Pv using the gobo 8 of drawing 6, and the synthetic image formation performance of Ph do not deteriorate [the time of using the gobo 8 of drawing 4 / especially].

[0028]It is provided in the radius r2 of the circular shade part of the center of the gobo 8 of drawing 6, and about 2<=0.4 r/sigma of 0.3 r/sigma<=r here, and the conditions of a<r2<b are also considered strictly. If the value of the radius r2 becomes small and is set to a>=r2 after all here, in order not to be different from the form of the gobo 8 of drawing 4 at all, the depth-of-focus expansion operation at the time of the image formation of the slanting patterns Ta and Tb will decrease a little. Conversely, since the surface light source form will approach the zona orbicularis if the value of the radius r2 is enlarged, the depth-of-focus expansion operation at the time of length, the horizontal pattern Pv, and the image formation of Ph will decrease.

[0029]Although drawing 7 shows the form by the 3rd embodiment of the gobo 8 and is fundamentally the same as the form of the gobo 8 of drawing 4, it is the inside of the zona-orbicularis-like shade part 8B of a periphery, and differs in that the very small shade parts 8C and 8D which have a corner of 90 degrees in a part of each four flabellate transparent parts 81a-81d were formed. These very small shade parts 8C and 8D had edge parallel to each of the X-axis and a Y-axis, only the distance dy has separated them from the X-axis in the direction of Y, and only the distance dx has separated a Y-axis and parallel edge from the Y-axis in the direction of X. The very small shade parts 8C and 8D in flabellate shade parts [81a-81d] each, It is provided in the furthest portion from each of the X-axis and a Y-axis, and the illumination luminous flux from the portion of these shade parts 8C and 8D has the orientation characteristic optimized to the thing which has the smallest pitch as the vertical pattern Pv and the horizontal pattern Ph, or the slanting pattern of a detailed pitch. For this reason, a depth-of-focus expansion operation is obtained at the time of the image formation of the length whose pitch is such the smallest, a horizontal pattern, or a detailed slanting pattern. However, illumination luminous flux will act in the direction which decreases the depth of focus rather in the middle from the portion of the shade parts 8C and 8D at the time of the image formation of the L&S pattern of the degree of detail of a degree (for example, line width of 0.4-0.5 micrometer).

[0030]Therefore, it can be said that the gobo 8 of drawing 7 is suitable for carrying out projection exposure of the reticle R which contains the L&S pattern of the degree of detail of a degree middle coarser than it although a detailed pattern in every direction is not included in the minimum pitch grade in which theory top image formation is possible with a modification light source system here. The distance dx of the edge of the very small shade parts 8C and 8D and dy are provided in dx<r and dy<r here, and if each pitch of the vertical pattern on a reticle, a horizontal pattern, and a slanting pattern is almost comparable, they will be further provided in dx=dy, so that clearly from drawing 7. And the position of each flabellate area pellucida [in the gobo 8 of drawing 7 / 81a-81d] area center-of-gravity point (light volume center-of-gravity point) is not changing so much with a center-of-gravity point position in case the very small shade parts 8C and 8D do not exist. If X of each edge of the very small shade parts 8C and 8D, the distance dx from a Y-axis, and dy are made small, each flabellate area pellucida 81a-81d approaches the rectangle (or square).

[0031]While drawing 8 makes comparatively small X of each edge of the very small shade parts 8C and 8D, the distance dx from a Y-axis, and dy, The form of the gobo 8 at the time of doubling each edge of the cross shape shade part 8A, the zona-orbicularis-like shade part 8B, and the very small shade parts 8C and 8D with the sectional shape (here, it is considered as a square) of the element lens of the fly eye lens 7 is shown. It is preferred that shade part edge doubles with the sectional shape of an element lens also previous drawing 4, drawing 6, and in each gobo of 7. the four area pellucida 81e-81h which forms the effective light source portion at the time of the image formation of the slanting patterns Ta and Tb in drawing 8 -- respectively — being alike — two element lenses are located on both sides of the X-axis and a Y-axis. The half the price a of the width of the cross shape shade part 8A is provided in

the size for one piece of an element lens, and length b is provided in the size for five pieces. And what removed one element lens of the outermost angle from the set of 4x4 element lenses is located in flabellate area pellucida [81a-81d] each. The portion equivalent to the very small shade parts 8C and 8D has covered two element lenses, respectively. in the case of the gobo 8 of this figure, the four flabellate area pellucida 81a-81d and area pellucida 81e-81h are not connected like each old embodiment, but are mutually-independent — the bottom is a thing. The shade part of the 4x4 same squares (or rectangle) as the size of the aggregate of an element lens may be added to the central part so that one element lens located in each innermost angle (corner nearest to the starting point) of the four more flabellate area pellucida 81a-81d may be covered. By addition of such a square shade part, the same operation as the gobo 8 of the 2nd embodiment shown in previous drawing 6 and an effect can be acquired. In this case, the distance from the X-axis of the edge of each neighborhood of a main quadrangle shade part and a Y-axis is provided in the range comparable as the radius C of the circular shade part of drawing 6.

[0032]The element lens group of the fly eye lens 7 located in flabellate area pellucida [which was furthermore shown in drawing 8 / 81a-81d] each is a symmetric design to the X-axis and a Y-axis altogether. By taking such symmetrical arrangement, the TERESEN error (strike slip of an image when a wafer surface shifts from a best focus side slightly) of the projection image of the L&S pattern on a reticle becomes that there is nothing.

[0033]When drawing 4, drawing 6 – the gobo 8 of eight are used with reference to drawing 9 here, distribution within pupil surface EP of the image formation light flux which occurred from the reticle R and entered into projection optical system PL is explained. The light volume center-of-gravity points 80A, 80B, 80C, and 80D of four fan-like surface light source parts which drawing 9 is what was expressed corresponding to drawing 2, and were optimized to the length of a predetermined pitch, the horizontal pattern Pv, and Ph, The length, the horizontal pattern Pv, and the one typical center-of-gravity point 80E out of four light volume center-of-gravity points optimized to slanting pattern Ta of the same pitch as Ph are shown on pupil surface EP. Each of the four center-of-gravity points 80A-80D is mostly in agreement with each area center of gravity of the four flabellate area pellucida 81a-81d in each embodiment.

The center-of-gravity point 80E is mostly in agreement with the area center-of-gravity point of the area pellucida 81e.

First, since the four center-of-gravity points 80A-80D are optimized to the pitch of the target length and a horizontal pattern, For example, by the exposure of the illumination light which passes along the center-of-gravity point 80A among the image formation light flux from the reticle R, the zero order light generated from length and a horizontal pattern passes along the center-of-gravity point 80A, and one side of the primary [**] diffracted light superimposes and passes along each of the X-axis and a Y-axis, and the center-of-gravity points 80B and 80D of being located symmetrically.

[0034]On the other hand, primary [**] diffracted-light**Dx_1 (center of gravity of diffracted luminous flux) generated from the vertical pattern Pv is distributed on a line parallel to the X-axis through the center-of-gravity point 80E with the illumination light by which orientation was carried out so that it may pass along the center-of-gravity point 80E, but. Since the position becomes the outside of the overall diameter of pupil surface EP like drawing 9, the image formation of the vertical pattern Pv is not affected. However, since one primary diffracted-light-Dy_1 (center of gravity of diffracted luminous flux) generated from the horizontal pattern Ph is distributed on the Y-axis in pupil EP, it affects the image formation of the horizontal pattern Ph. Since this primary diffracted-light-Dy_1 differs in the ideal distribution position by the deformation illumination method of the horizontal pattern Ph, it is a light which is not so preferred for the image formation of the horizontal pattern Ph. however, the amount of illumination light which makes the center-of-gravity point 80E is decided by the area pellucida 81e of a small area, is markedly boiled compared with the amount of illumination light of other four center-of-gravity points 80A-80D, and is small. in the case of drawing 8, the ratio is decided by the ratio of the number of the element lenses of the fly eye lens 7, therefore is not preferred -- it is markedly alike, and the light volume of primary diffracted-light-Dy_1 itself is small, and it does not degrade the image formation performance of the horizontal pattern Ph greatly practically.

[0035]Next, distribution of the image formation light flux from slanting pattern Ta (45 degrees) is considered. Here, the diffracted light generated from slanting pattern Ta by the exposure of the illumination light (transparent part of the flabellate area pellucida 81b) by which orientation was carried out so that it might represent and a zero order light might pass along the center-of-gravity point 80B is described. Supposing the pitch of slanting pattern Ta is comparable as length, the horizontal pattern Pv, and the pitch of Ph, primary diffracted-light-Dt_1 (center of gravity of diffracted luminous flux) from slanting pattern Ta, the circle top of radius 2yalpha (or 2xbeta) centering on the center-of-gravity point 80B — and it is located on the line (135 degrees) which connects the center-of-gravity points 80B and 80B through the optic axis AX. Since this primary diffracted-light-Dt_1 does not have a zero order light bunch which passes along the center-of-gravity point 80B, and a symmetrical relation about the 45-degree line which connects the two center-of-gravity points 80A and 80C, it is the light which is not preferred to the image formation of slanting pattern Ta.

[0036]However, since the area pellucida 81e is formed in the gobo 8 so that the zero order light from slanting pattern Ta may be located in the center-of-gravity point 80E, the circle top of centering on center-of-gravity point 80E radius [' / which was generated from slanting pattern Ta by the illumination light from the area pellucida 81e / primary diffracted-light-Dt_1] 2yalpha (or 2xbeta) — and it is located on the 135-degree line (parallel to the line which connects the center-of-gravity points 80B and 80D) which passes along the center-of-gravity point 80E. The physical relationship of the center-of-gravity point 80E and primary diffracted-light-Dt_1' is almost symmetrical to the 45-degree line (medial axis in the Fourier transform image of slanting pattern Ta) which connects the center-of-gravity points 80A and 80C. Therefore, the illumination light from the area pellucida 81e becomes an effective ingredient to the image formation of slanting pattern Ta, and works in the direction which improves the resolution and the depth of focus of a slanting pattern. In the case of drawing 9, primary diffracted-light-Dt_1' from slanting pattern Ta which makes the center-of-gravity point 80E a zero order light is located on about X axes, and the position is approaching the center-of-gravity point (referred to as 80H) of the illumination light from other area pellucida 81h for the slanting patterns of the gobo 8 further. Thus, that the center-of-gravity point 80H of the area pellucida 81h is located in the position of primary diffracted-light-Dt_1' means that slanting pattern Ta is illuminated by two illumination luminous flux symmetrically inclined in the pitch direction.

[0037]If it is comparable on the length which should be carried out projection exposure, the horizontal pattern Pv, Ph, and the reticle in which each pitch of the slanting patterns Ta and Tb is one sheet from the above thing, What is necessary is just to arrange ideally

each light volume center-of-gravity point of the surface light source part (area pellucida 81e-81h) added to slanting patterns from the starting point to the place of the distance of root (xbeta^2+yalpha^2) on the X-axis and a Y-axis. This relation is ideal conditions, and actually, even if shifted from that relation a little (for example, 20% - about 30%), as it is, the effect of this invention is acquired.
[0038]Drawing 10 changes the portion of the fly eye lens 7 which showed the partial composition of an illumination-light study system by the 4th embodiment of this invention, and was shown in drawing 3 here into the fly eye lens system of two reams which are indicated by JP,H3-78607,B. The illumination light ILa which passed along the collimating lens 4 and the prism 30 in drawing 3 enters into the 1st step of fly eye lens 7E like drawing 10. This fly eye lens 7E should bundle every four element lenses in X and the direction of Y. The illumination light from each of the point light source image which carried out image formation to the injection end of each element lens of the fly eye lens 7E superimposes and irradiates with the whole surface of the entrance plane of the 2nd step of fly eye lens 7F via the lens system 25. The 2nd step of fly eye lens 7F is what bundled the element lens in 6x6 arrangement, and image formation of the three-dimensional light source image (point light source) is carried out all over the space distant from the projection surface of each element lens about several millimeters. In the case of this 2 ream fly eye lens system, to the injection side of each element lens of the 2nd step of fly eye lens 7F. Since 4x4 point light source images formed in the projection surface of the 1st step of fly eye lens 7E are formed, a three-dimensional light source image serves as the surface light source in which the 16x36 point light sources gathered in two dimensions.
[0039]Now, in the case of this example, the gobo 8 shown in drawing 4, drawing 6 - 8 is an injection side of the 2nd step of fly eye lens 7F, and is arranged in the field in the space in which a three-dimensional light source image is formed. Drawing 11 shows the arrangement relationship of the three-dimensional light source image and each edge of the shade parts 8A (8A') and 8B of the gobo 8 which were formed in the injection side of the fly eye lens 7F. As shown in drawing 11, 4x4 point light source SP has lined up in X and the direction of Y in even pitch mostly at the one element lens's injection side of the fly eye lens 7F. At this time, all of the outside edge of the cross shape shade part 8A (8A') or the edge corresponding to the inside diameter circle C1 of the surrounding zona-orbicularis-like shade part 8B are crooked according to the pitch of the point light source which forms a three-dimensional light source image. That is, as shown in drawing 8 at the time of a single fly eye lens system, the edge of each shade part needed to be specified according to the sectional shape of the element lens of a fly eye lens, but there is no such necessity in 2 ream (tandem) fly eye lens system. and since the number of the point light sources which form a three-dimensional light source image is boiled markedly and is increasing rather than the case of a single fly eye lens system, the average illuminance distribution as the surface light source becomes very flat.
[0040]Drawing 12 as the composition of the illumination system brought near by the 5th embodiment of this invention is shown and it is indicated by JP,H4-225514,A here, The surface light source for patterns in every direction located in each of four quadrants by the XY coordinate system on the Fourier transformation plane within an illumination system consists of the fly eye lenses 70A, 70B, 70C, and 70D which became independent, respectively. And the pyramid prism 26 divides the illumination luminous flux of the zona-orbicularis-like distribution from the collimating lens 4 into four light flux, and each is entered into the four fly eye lenses 70A-70D. The surface light source for slanting patterns The point 70E of the four optical fibers 90, It constitutes from 70F, 70G, and 70H, and the four other end (incidence edge) side of the optical fiber 90 is bundled by one, and a part of illumination light which branched after the shutter 19A is condensed by the incidence edge.
[0041]Since the system which makes the surface light source for slanting patterns from this example is independently with the system which makes the surface light source for patterns in every direction, When the slanting pattern does not exist at all on the reticle used as a projecting object, into the optical path by the side of the incidence edge of the optical fiber 90, an another shutter and dark filter (ND filter) can be inserted, and luminescence of the points 70E-70H can be forbidden, or a light volume fall can be carried out substantially. Since the luminescence intensity of the points 70E-70H can be changed by adjustment of the fading rate of the ND filter, etc., the optimal light volume can be given according to the rate that a slanting pattern closes among the L&S patterns on the reticle R. Therefore, if the operator makes the information about the rate of the slanting pattern on the reticle R the composition inputted into the main control unit 20 in drawing 3, the luminescence intensity of the four points 70E-70H can also be automatically adjusted to an optimum value (zero are also included) according to the table which was able to be defined beforehand. As shown in drawing 12, the four fly eye lenses 70A-70D, Since the four points 70E-70H are formed independently, according to the pitch of the pattern of L&S on the reticle R, each fly eye lens or a point may be made movable to two dimensions or one dimension in XY side. In that case, the light volume center-of-gravity point of the surface light source by the side of each injection of the fly eye lenses 70A-70D the pitch of an in every direction pattern and slanting pattern is comparable, and is [fly eye lenses] four, When taking the arrangement corresponding to four corners of the square centering on the optic axis AX in XY side, it is good to make it movable by a relation to which the eccentricity from the optic axis AX of the light volume center-of-gravity point of the four fly eye lenses 70A-70D and the eccentricity from the optic axis of the light volume center-of-gravity point of the points 70E-70H become almost equal.
[0042]In the composition of drawing 12, each of the four fly eye lenses 70A-70D, A diaphragm (gobo) is individually provided in each injection side of each fly eye lenses 70A-70D, and it interlocks and may be made to often also as a tandem fly eye lens system change each size of the four surface light sources individually like drawing 10. By the way, in drawing 12, although the gobo etc. are not specially provided between each of the fly eye lenses 70A-70D, when so large that the stray light passing through the space between each fly eye lens cannot be disregarded, it is desirable to provide an easy gobo (cross shape). Therefore, if the stray light component is small enough, it is not necessary to provide a gobo specially. This is similarly applicable to the gobo 8 shown in previous drawing 4, drawing 6 - 8, and means that it is not necessary to make the cross shape shade parts 8A and 8A, the zona-orbicularis-like shade part 8B, etc. into a perfect light shielding layer. For example, each shade part on the gobo 8 may consist of dielectric membrane etc. which have a fading rate of not less than 90% in the wavelength (i line 365 nm and a KrF excimer laser 248 nm) of the illumination light for exposure.
[0043]Now, the example of the diaphragm form of the conventional modification light source announced here until now for explanation of the following simulations is shown in drawing 13 and 14. Drawing 13 is the center position (xbeta, yalpha) optimized by the vertical pattern Pv which has a specific pitch, and the horizontal pattern Ph, and an example of the gobo for circular 4 light sources which has a suitable radius (it is 0.1-0.3 at a sigma value). Drawing 14 is an example of the larger gobo for flabellate 4 light sources than the radius r in which it is considered as a square opening instead of the circular opening of drawing 13, respectively, and a part of these

four surrounding square openings are equivalent to the sigma value of an illumination-light study system.
[0044]The line of the L&S pattern image acquired as an example at the time of projection of the in-every-direction L&S pattern using the light source configuration shown in drawing 14, and a slanting (45-degree or direction of 135 degree) L&S pattern, or the line width size of a space Depth-of-focus DOF to [mum] The simulation result of [mum] is shown in drawing 15. The conditions of a simulation are the wavelength lambda here 0.365 of i line [mum] Numerical aperture N.A. by the side of the wafer of projection optical system PL 0.50 (the reticle side 0.1), Half the price a of the width of 0.8 (the sigma value of the usual circular surface light source is also set to 0.8) and a cross shape shade part was made into 0.28, i.e., a=0.28 r/sigma =0.35r, by numerical aperture conversion by making the inside diameter r of the zona-orbicularis-like shade part 8B of the gobo 8 into a sigma value (r/r_0) (usually with [in Lighting Sub-Division / a= 0] no cross shape shade part). The constant value, 1.2/1.7**0.706 as which the value of the depth of focus (DOF) is decided by 1.2 micrometers in thickness of the resist which should be carried out a patterning, and its refractive index 1.7 here from the range (overall width) from which the contrast of a 1:1 line-and-space (last shipment) pattern image will be not less than 60% It was considered as the value which deducted [mum]. Characteristic DV1 of the simulation result expressed with the two-dot chain line in drawing 15, The depth-of-focus characteristic to length when the conventional gobo of drawing 14 is used, and a horizontal L&S pattern is shown, and simulation property DO1 of a dashed line shows the depth-of-focus characteristic to a slanting (45-degree, 135 degrees) L&S pattern when the gobo of drawing 14 is used similarly. In the conventional modification light source configuration like drawing 14, depth-of-focus characteristic DO1 to a slanting pattern results in it being slightly inferior to depth-of-focus characteristic DC to a slanting pattern when the usual circular surface light source simulated for comparison is used. In the case of the usual circular light source form, it is set to depth-of-focus characteristic DC also to any of length, width, and a slanting pattern.
[0045]Drawing 16 shows the simulation result of the depth-of-focus characteristic when the gobo 8 by the 1st embodiment (drawing 4) of this invention is used. At this time, the half the price a of the width of the cross shape shade part 8A in drawing 4 was provided in $a=0.28r_0=0.35r$, and the half the price b of length set it to $b=0.56r_0=0.7r$, and it made the exposure wavelength lambda, N.A., and sigma the same as the case of drawing 15. Although depth-of-focus characteristic DV2 in the L&S pattern of 1:1 in every direction in this condition is slightly inferior to characteristic DV1 by the conventional modification light source (drawing 14) in drawing 15, On the other hand, the top [DC / when the usual circular surface light source is used / depth-of-focus characteristic] is turning around depth-of-focus characteristic DO2 to a slanting L&S pattern, and the effect of this invention is checked. There is enough depth-of-focus characteristic DV2 to a pattern in every direction, and the capability which a modification light source has intrinsically is not spoiled. Although the half the price a of the width of a cross shape shade part and half the price b of length were made into $a=0.28r_0$ (0.28 time of numerical aperture N.A. of a projection optical system), and $b=0.56r_0$ (0.56 time of numerical aperture N.A.) in this simulation, respectively, As these values are not limited to it and described previously, the value a should just be a $0.1r_0$(0.1 and N.A.) $<=a<= 0.4r_0$ (0.4 and N.A.) grade, About the value b, it is $0.4r_0$(0.4 and N.A.) $<=b< 0.8r_0$ (0.8 and N.A.). If it is a grade, the effect of this invention can be acquired. However, the maximum of the value b needs to be b<r to the value of the radius r.
[0046]Drawing 17 shows the simulation result of the depth-of-focus characteristic when the gobo 8 by the 2nd embodiment (drawing 6) of this invention is used. At this time, the gobo 8 is what combined the cross shape shade part and the center circle form shade part as it was shown in drawing 6, A simulation condition the half the price a of the width of 0.7 and a cross shape shade part by sigma value (r/r_0) conversion for the inside diameter r of 0.50 and the zona-orbicularis-like shade part 8B of the periphery of the gobo 8 $0.28r_0$, [the exposure wavelength lambda] [wafer side numerical aperture N.A. of 0.365 micrometer (i line) and projection optical system PL] The radius c of $0.56r_0$ and a center circle form shade part was made into $0.46r_0$ for the half the price b of length. like the simulation result of drawing 17, compared with depth-of-focus characteristic DC in the conventional usual circular surface light source (sigma=0.7), depth-of-focus characteristic DO3 of a slanting L&S pattern is boiled markedly, and it improves.
And depth-of-focus characteristic DV3 to length and a horizontal L&S pattern has a value big enough.

[0047]Although the value of the radius c of a center circle form shade part was made into 0.46 r/sigma in the simulation here, the half the price a and b of the above-mentioned [this] — similarly it is not necessarily limited to 0.46 r/sigma — if it is a 0.3 r/sigma (0.3 and N.A.) <c< 0.6 r/sigma (0.6 and N.A.) grade, the effect of this invention can fully be acquired. However, since the gobo 8 of drawing 6 will serve as the same form as the gobo of drawing 4 if the value of the radius c is too small, the improvement factor of the depth of focus about a slanting pattern will decrease a little. That is, characteristic DO3 in drawing 17 becomes like characteristic DO2 in drawing 16. If the value of the radius c is not much large, in depth-of-focus characteristic DV3 to a L&S pattern in every direction, the portion to which the depth of focus that pattern size is seen near 0.45 micrometer becomes large especially stops existing, and it is not desirable too in order to approach zona-orbicularis Lighting Sub-Division (after-mentioned).
[0048]Drawing 18 shows a simulation result when the gobo 8 by the 3rd embodiment (drawing 7) of this invention is used. The simulation condition in this case the sigma value (r/r_0) which is a maximum radius of 0.50 and the surface light source about numerical aperture N.A. of a projection optical system Each size of 0.8 and the cross-joint shade part 8A, Distance d to $0.28r_0$, $0.56r_0$, and the minute protection from light 8C and 8D of the circumference was made into $0.64r_0$ for the half the price a and the half the price b, respectively. If the simulation result of this drawing 18 is compared with the simulation result shown in above-mentioned drawing 16, depth-of-focus characteristic DO4 about a slanting pattern when the gobo 8 of drawing 7 is used, Being improved to the same extent as depth-of-focus characteristic DO3 (drawing 17) when the gobo of depth-of-focus characteristic DO2 (drawing 16) when the gobo 8 of drawing 4 is used, or drawing 6 is used. It turns out especially among L&S patterns in every direction that the depth of focus is improved like depth-of-focus characteristic DV4 also about the pattern of the degree of detail of the degree of middle with a linewidth of about 0.45 micrometer.
[0049]The value of the edge distance d of the minute shade parts 8C and 8D in the gobo of drawing 7 is not necessarily limited to $0.64r_0$, either, and should just be a range about $0.5r_0<d<0.8r_0$. However, when the distance d is not much small, the resolution to a pattern in every direction will fall, and if not much large, an effect will not appear. Then, a center circle form shade part like drawing 6 which shades further the neighborhood of an optic axis of the gobo 8 shown in drawing 7, or a quadrangle shade part may be added.

[0050]Drawing 19 shows the same simulation result in zona-orbicularis Lighting Sub-Division for comparison. The conditions at this time consider the zona-orbicularis-like surface light source which made the shade part the center circle form part which is equivalent to the radius (sigma=0.35) of that half among the circular surface light sources of the radius which sets the exposure wavelength lambda to 0.365 micrometer, and is equivalent to 0.7 and N.A. (sigma=0.7). At depth-of-focus characteristic DA to the L&S pattern obtained with such zona-orbicularis Lighting Sub-Division, the depth of focus of about about 1.5 micrometers is obtained by width about a coarse pattern with a line (or space) width of 0.42 micrometers or more. In depth-of-focus characteristic DC at the time of the conventional circular surface light source, the actual condition is that 1 micrometer cannot be found, either. However, considering the time of exposure of a actual memory pattern, the especially big depth of focus in the exposure process of a metallic wiring layer is required, for example, the depth of focus of not less than 2 micrometers is needed by width to a L&S pattern with a line width of about 0.45 micrometer by 64MDRAMs. Therefore, it is difficult like drawing 19 to fill this demand with depth-of-focus characteristic DA obtained with zona-orbicularis Lighting Sub-Division. Since that especially the depth of focus is needed also by the exposure process of an above-mentioned metallic wiring layer is the length and the horizontal L&S pattern which are formed in the level difference (about 1 micrometer) part, a modification light source configuration like this invention is very effective.
[0051]Although i line shall be used by using a light source as a mercury lamp into an embodiment, this may be other wavelength or may be light sources, such as laser. Although numerical aperture N.A. of the projection optical system was set to 0.5 and the radius r of the greatest surface light source made with a gobo was set to 0.7 or 0.8 by the sigma value on condition of the simulation, numerical aperture N.A. and a sigma value are not limited to this. However, about a sigma value, more than [about 0.7] are effective. Although the outermost form of a light source configuration shall be restricted by the circle (sigma) specified with the inside diameter edge of the zona-orbicularis shade part 8B of the gobo 8, a quadrangle, a hexagon, etc. may prescribe the outermost form. Although shade part form of the gobo 8 in each embodiment was furthermore made into the shape of isomorphism (symmetric figure) about the direction of X, and the direction of Y, the form may differ in the direction of X, and the direction of Y. That is, the direction of X may differ in the value of the distance c from the center of each edge at the time of providing a quadrangle shade part in the dimension value a, b, and d or center of each shade part from the direction of Y.
[0052]In a actual illumination system, the luminous energy distribution of the projection surface of a fly eye lens serves as a discrete set of the point light source discretely according to the arrangement of each element lens of a fly eye lens. At this time, each intervals of the discrete point light source also differ that the sectional shape of each element lens is a rectangle in X and the direction of Y. Then, in order to arrange effectual Lighting Sub-Division conditions (orientation characteristic of the illumination light to a reticle) in X and the direction of Y, it may be necessary to change positively the dimension value a, b, and c of each shade part, and the value of d in X and the direction of Y. In order to centralize the illumination light efficiently to each transparent parts 81a-81d, 81e-81h of the gobo 8 used in each embodiment of this invention and to reduce a light volume loss, it is good to establish the condensing means (prism, a mirror, a fiber, etc.) on which those transparent parts are made to concentrate the illumination light in front of the gobo 8. Although the gobo 8 of each embodiment presupposed that a transparent part and a shade part are comprised, it is still better also considering a part or all of shade parts as a semi transmission part (transmissivity is 50% or less desirably). moreover — preparing for the turret 10 of drawing 3 two or more gobos 8 which had the form which can respond to them by the process of exposing since the required depth of focus and importance of a pattern in every direction and a slanting pattern differed from each other -- exchange -- the thing it is supposed that it is usable is desirable. Although the reticle to be used was made into the usual reticle which comprises a shade part (chromium layer) and a transparent part in the simulation, If this invention is used at the time of projection of the so-called reticle of a half-tone phase shift (half-tone transparent part (thin film) from which only pi makes phase between lights which have transmissivity of about 1 to 15% instead of shade part, and pass along transparent part differ is provided) system, the effect of this invention can be heightened further.
[0053]The gobo 8 shown in each embodiment is acting on an improvement of the depth of focus good at the time of about 0.4-0.5 micrometer for which the line width on the pattern Pv in every direction and the wafer of Ph is used at the time of 64 M-DRAM manufacture so that clearly from each above simulation result. And the improvement effect of the depth of focus is simultaneously acquired also about the slanting patterns Ta and Tb. However, if the depth of focus in the same line width size is measured by the pattern in every direction and a slanting pattern, to be sure, the depth of focus in the direction of a slanting pattern is not so large. However, the pitch (line width size) of the pattern in every direction within the reticle of one sheet is received, When the pitch (line width size) of a slanting pattern is coarser about 1.2 to 1.5 times, for example line width size is 0.42 micrometer in characteristic DV3 to the pattern in every direction in drawing 17, About 2 micrometers of depths of focus in line width size 0.63micrometer in characteristic DO3 [as opposed to / that it is the 1.5 times (0.63 micrometer) the line width size of a slanting pattern of this / a slanting pattern] will be obtained.
[0054]By the way, when the four light volume center-of-gravity points (center-of-gravity point of a zero order light) 80A-80D optimized to the pitch of the target pattern in every direction are located in each square angle within pupil EP of projection optical system PL so that clearly from previous drawing 9, When the pitch of the target slanting pattern is about 1.4 times of the pitch of a pattern in every direction, the light volume center-of-gravity point 80E of the illumination light added auxiliary to slanting patterns is ideally in agreement with the intersection of the line segment and Y-axis which connect the two center-of-gravity points 80A and 80B.
[0055]Drawing 20 shows signs that each light volume center-of-gravity point has been arranged by the almost ideal relation, when the pitch relation [about 1.4 times] between a pattern in every direction and a slanting pattern is above. The zero order light and the primary diffracted light which are distributed over pupil EP in this drawing 20 shall have breadth in the surroundings of each center-of-gravity point in a predetermined size. Originally, although it is in agreement with the form of the surface light sources, such as the area pellucida 81a-81d, 81e-81h of the gobo 8, the form (field) of the breadth is only circular here, and is expressed.
[0056]primary diffracted-light-Dt_1 corresponding to each of four zero order lights (center-of-gravity points 80A-80D) which are generated from a slanting pattern (45 degrees, 135 degrees) in the case of drawing 20 — pupil EP — it superimposes and passes along a center mostly. Primary diffracted-light-Dt_1' from the slanting pattern which passes along the center-of-gravity point 80E as a zero order light passes along the congruous positions near [each] the center-of-gravity points 80H and 80F of the source of a fill-in flash for slanting patterns. Simultaneously, primary diffracted-light-Dy_1 from the horizontal pattern which passes along the center-of-

gravity point 80E as a zero order light passes along the congruous positions near the center-of-gravity point 80G of the source of a fill-in flash for slanting patterns.
[0057]The four primary diffracted lights to which the ingredient which reduces the depth-of-focus expansion effect over a slanting pattern when a modification light source is used among distribution of such a zero order light and the primary diffracted light appears in the center of pupil EP - It is Dt_1. So, at the time of such conditions, it is good to arrange a dark filter (ND filter) only in the center section of the pupil EP of a projection optical system, and to attenuate four light volume of primary diffracted-light-Dt_1 moderately.
[0058]The arrangement relationship of the circular area which makes the four light volume center-of-gravity points 80A-80D for the patterns in every direction in drawing 20, and the small circular area which makes the four light volume center-of-gravity points 80E-80H for slanting patterns becomes the area-pellucida form of the gobo 8 for modification light sources and similarity which are provided in an illumination system as it is. Therefore, as the gobo 8, the thing of the form which made transparent four big circular areas in drawing 20 and four small circular areas can be used as it is.
[0059]
[Effect of the Invention]As mentioned above, according to this invention, degradation of the image formation performance to the slanting pattern made into the problem with the modification light source until now, especially a depth-of-focus improvement factor can be prevented, and the almost same performance as the conventional modification light source can be obtained also about a pattern in every direction.

[Translation done.]

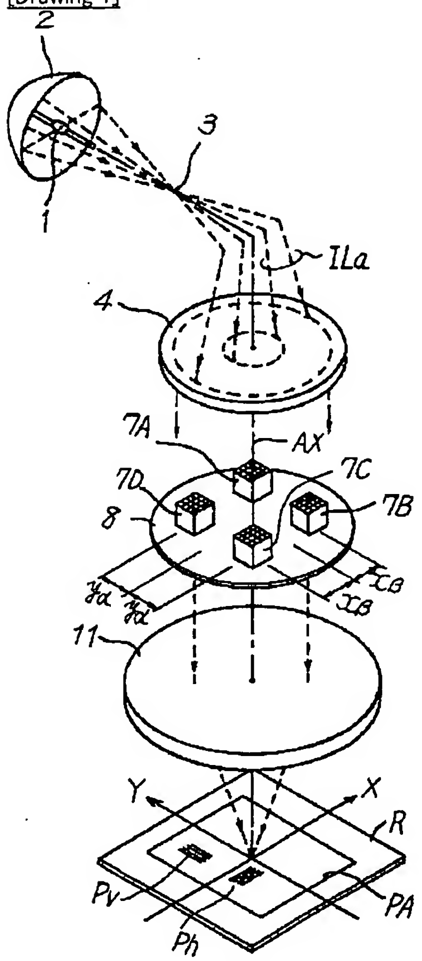
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]The perspective view of an illumination system with the modification light source used as the foundation of this invention.
[Drawing 2]The figure showing the theoretic form of the modification light source by this invention.
[Drawing 3]The figure showing the entire configuration of the projection aligner as an embodiment of this invention.
[Drawing 4]The figure showing the form of the gobo for modification light sources by the 1st embodiment.
[Drawing 5]The figure showing an example of the period directions of the L&S pattern on a reticle.
[Drawing 6]The figure showing the form of the gobo for modification light sources by the 2nd embodiment.
[Drawing 7]The figure showing the form of the gobo for modification light sources by the 3rd embodiment.
[Drawing 8]The figure showing an example of the arrangement relationship of the form of the gobo of drawing 7, and a fly eye lens.
[Drawing 9]The figure showing typically the luminous flux distribution in the pupil surface of a projection optical system when the modification light source shown in each embodiment is used.
[Drawing 10]The figure showing the composition of a part of illumination system by the 4th embodiment.
[Drawing 11]The figure showing the form of the suitable gobo for the illumination system of drawing 10.
[Drawing 12]The figure showing the composition of a part of illumination system by the 5th embodiment.
[Drawing 13]The figure showing the form of the gobo for the conventional modification light sources.
[Drawing 14]The figure showing the form of the gobo for the conventional modification light sources.
[Drawing 15]The graph which shows the simulation result of the depth-of-focus characteristic when the gobo of drawing 14 is used.
[Drawing 16]The graph which shows the simulation result of the depth-of-focus characteristic when the gobo of drawing 4 is used.
[Drawing 17]The graph which shows the simulation result of the depth-of-focus characteristic when the gobo of drawing 6 is used.
[Drawing 18]The graph which shows the simulation result of the depth-of-focus characteristic when the gobo of drawing 7 is used.
[Drawing 19]The graph which shows the simulation result of the depth-of-focus characteristic when zona-orbicularis Lighting Sub-Division is performed.
[Drawing 20]The figure showing typically the luminous flux distribution in the pupil surface of a projection optical system when the modification light source by this invention is used.
[Explanations of letters or numerals]
1 .... Mercury lamp
7, 7A-7F and 70A-70D .... Fly eye lens
70E-70H .... Optical fiber tip
8 .... Gobo
11 .... Condenser lens
R .... Reticle
PL .... Projection optical system
W .... Wafer

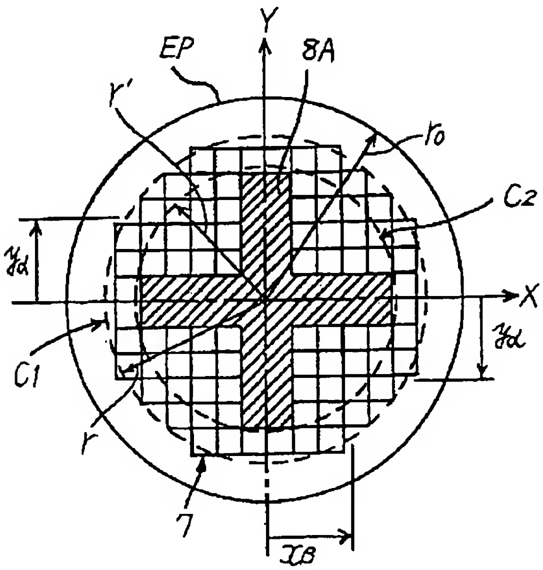
[Translation done.]

DRAWINGS

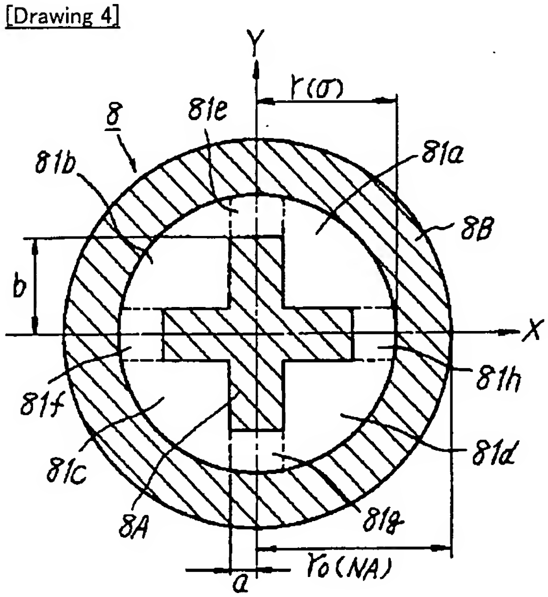
[Drawing 1]



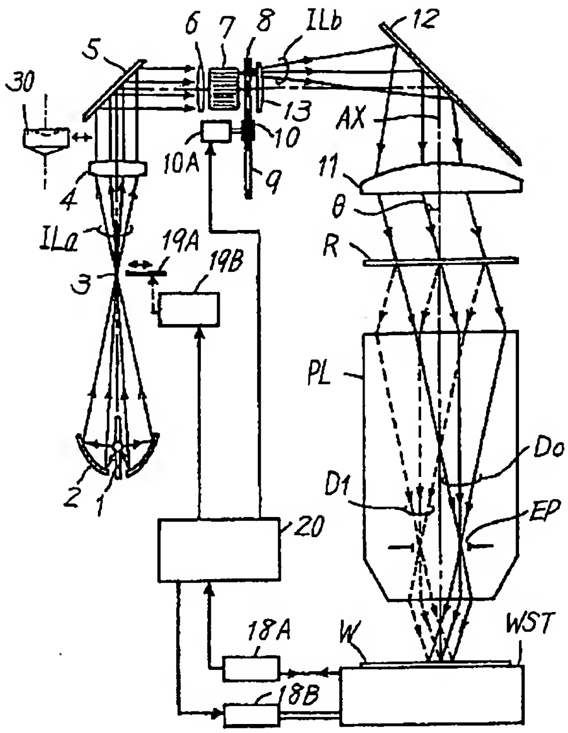
[Drawing 2]



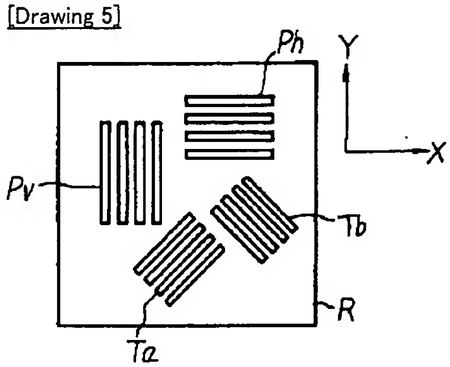
[Drawing 4]



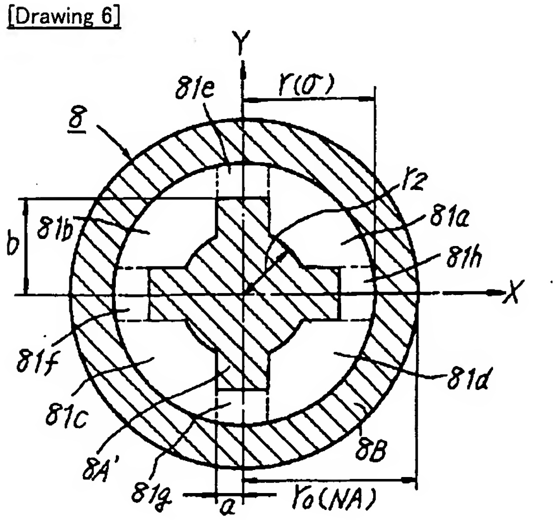
[Drawing 3]



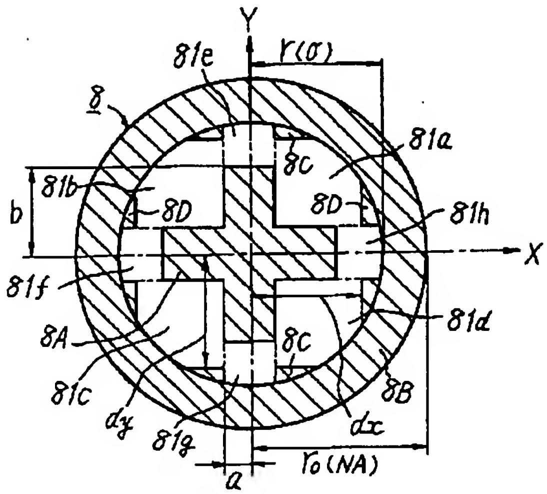
[Drawing 5]



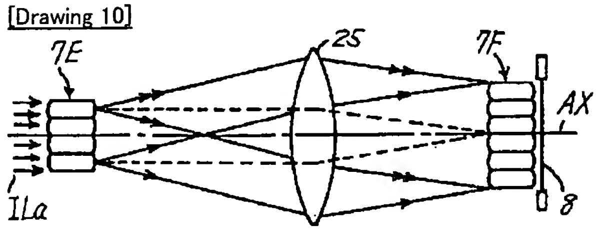
[Drawing 6]



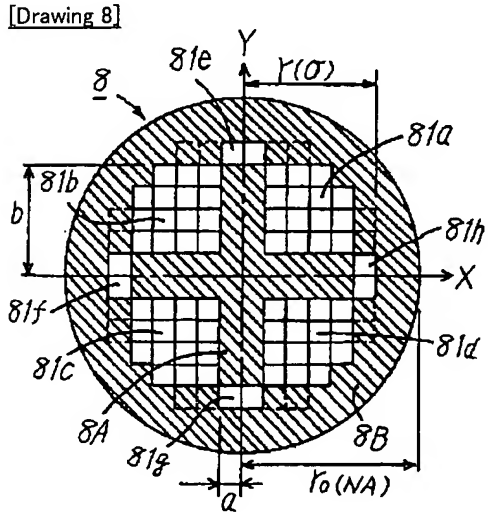
[Drawing 7]



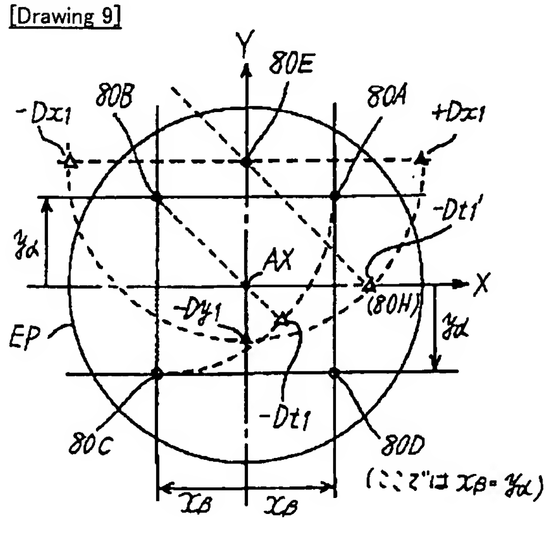
[Drawing 10]



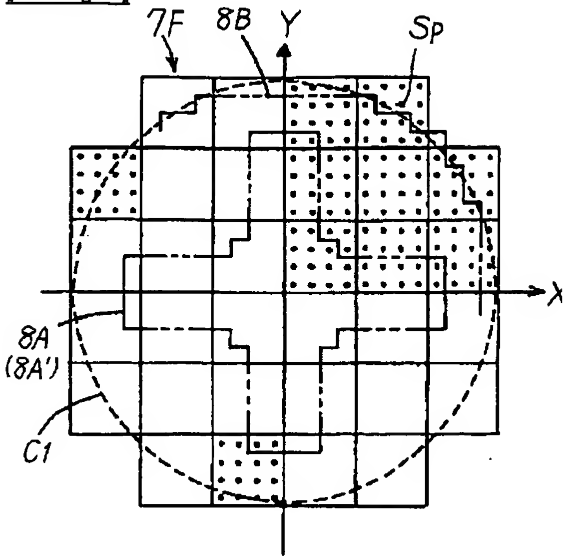
[Drawing 8]



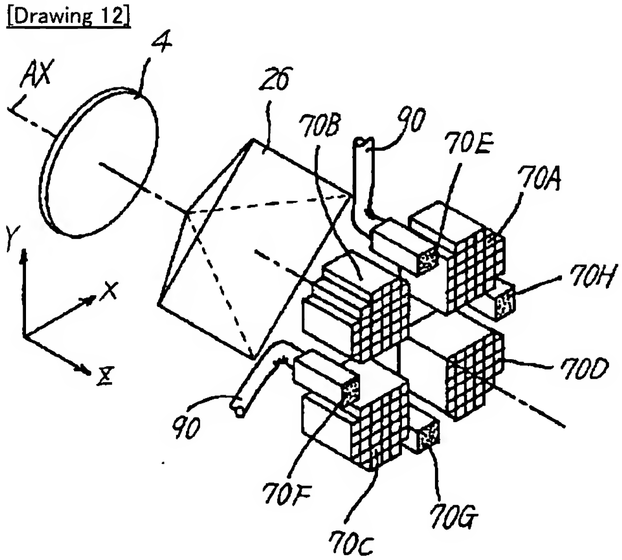
[Drawing 9]



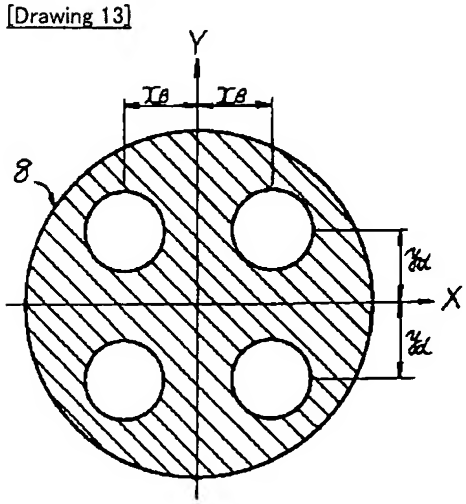
[Drawing 11]



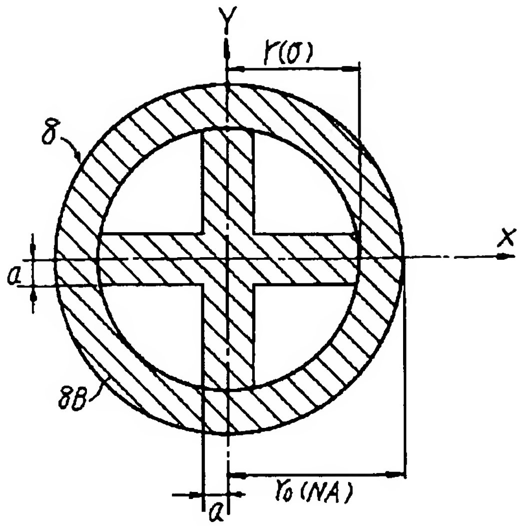
[Drawing 12]



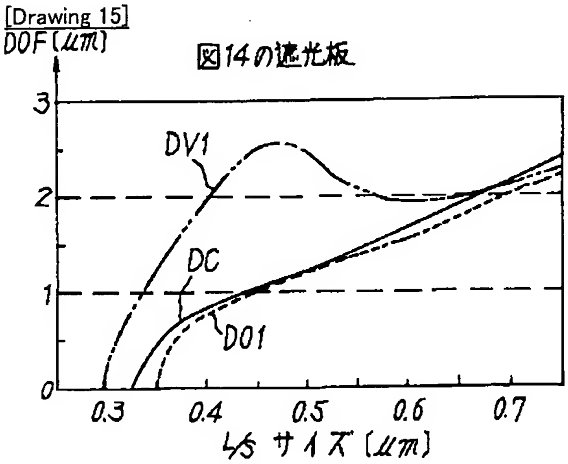
[Drawing 13]



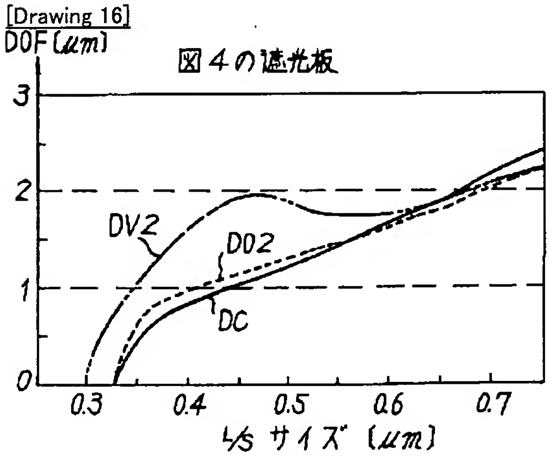
[Drawing 14]



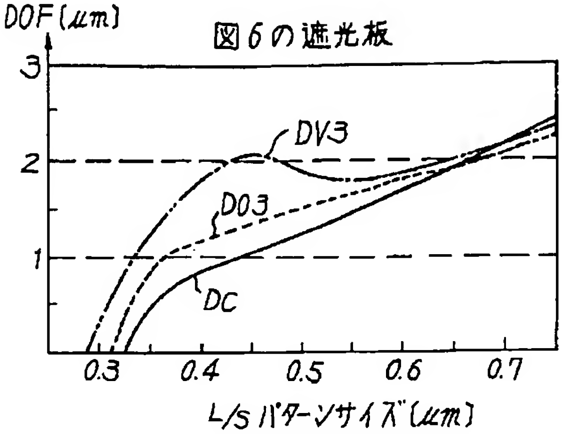
[Drawing 15]



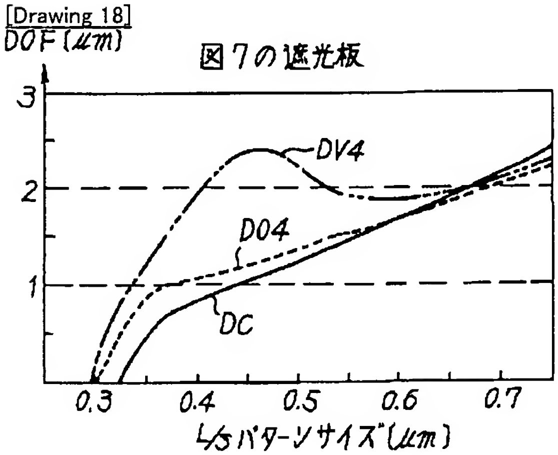
[Drawing 16]



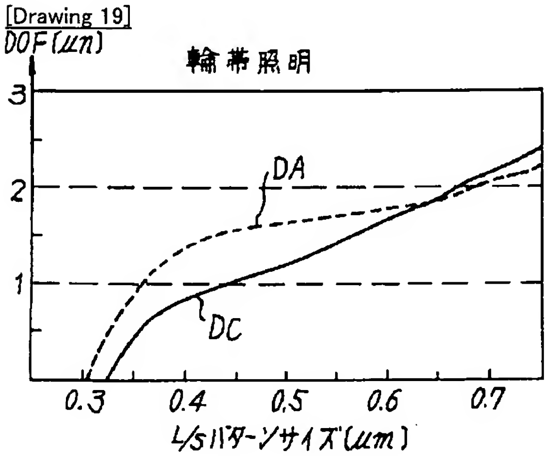
[Drawing 17]



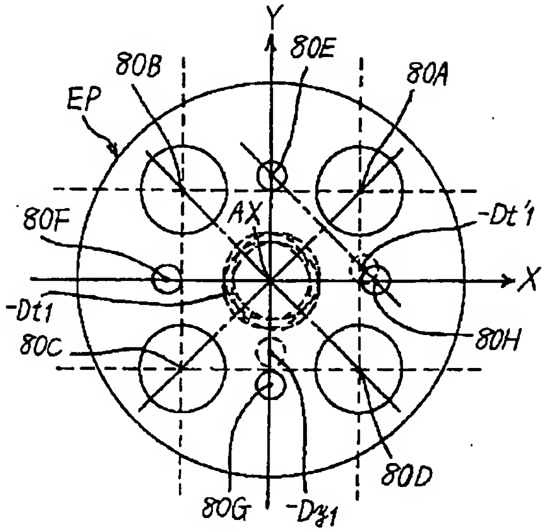
[Drawing 18]



[Drawing 19]



[Drawing 20]



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette]Printing of amendment by regulation of Patent Law Article 17 of 2
[Section Type] The 2nd Type of the part VII gate
[Publication date]Heisei 13(2001) March 23 (2001.3.23)

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27/54

G03F 7/20 521
[FI]

H01L 21/30 311 S

G03B 27/32 F

27/54 Z

G03F 7/20 521

H01L 21/30 311 L
[Written Amendment]
[Filing date]Heisei 11(1999) December 20 (1999.12.20)
[Amendment 1]
[Document to be Amended]Description
[Item(s) to be Amended]Title of invention
[Method of Amendment]Change
[Proposed Amendment]
[Title of the Invention]A projection aligner and a method
[Amendment 2]
[Document to be Amended]Description
[Item(s) to be Amended]Claims
[Method of Amendment]Change
[Proposed Amendment]
[Claim(s)]
[Claim 1]In a projection aligner provided with an illumination system which illuminates a mask in which a pattern which should be projected was formed, and a projection optical system which projects an image of said pattern on a sensitized substrate,
Said illumination system contains an illumination-light study system which has a field which serves as a relation of the Fourier transform optically to a pattern surface side of said mask inside, and a light distribution setting-out means to distribute illumination light in a predetermined radius centering on an optic axis on said Fourier transformation plane or its nearby surface,
A projection aligner, wherein said light distribution setting-out means distributes said illumination light over two or more discrete fields except the central part by the inside of a field of the shape of said zona orbicularis while distributing said illumination light in a field of the shape of zona orbicularis of specified width centering on said optic axis.
[Claim 2]The projection aligner according to claim 1 dividing by a rectangular coordinate system characterized by comprising the following which said two or more fields make said optic axis the starting point including the 2nd element, and is specified corresponding to said 2-way.
The 1st element that has periodicity in a 2-way a 2-way and said pattern cross at right angles mutually, respectively.
It is periodicity to a direction which intersects said 2-way.

[Claim 3]If width of r_0 and said cross-joint field is set to 2xa and length is set to 2xb, a radius of a pupil surface of said projection optical system which said two or more fields were divided in a cross-joint field specified on said rectangular coordinate system centering on said optic axis, and was seen on said Fourier transformation plane, 0. The projection aligner according to claim 2 filling $1r_0$<=a<=$0.4r_0$ and $0.4r_0$<=b<=$0.8r_0$.

[Claim 4]The projection aligner according to any one of claims 1 to 3 which will be characterized by the radius r2 of said central part filling $0.3r_0$<=r2 <=$0.4r_0$ if said central part is circular and a radius of a pupil surface of said projection optical system seen on said Fourier transformation plane is made into r_0.

[Claim 5]If a radius of a pupil surface of said projection optical system which said illumination light was distributed in said two or more fields in addition to a part of outer edge section, respectively, and was seen on said Fourier transformation plane is made into r_0, said light distribution setting-out means, The projection aligner according to any one of claims 1 to 4, wherein the distance d with an axis of coordinates of said rectangular coordinate system fills $0.5r_0$<d<$0.8r_0$ said a part of outer edge section.

[Claim 6]A light source which generates illumination light with which a mask is irradiated, and an illumination-light study system which forms a secondary light source of said light source in a Fourier transformation plane which serves as a relation of the Fourier transform optically to a pattern surface side of said mask, or its nearby surface, In a projection aligner provided with a projection optical system which enters light from a pattern of said mask irradiated by illumination light from said illumination-light study system, and projects an image of said pattern on a sensitized substrate,
The 1st element that has periodicity in a 2-way a 2-way and said pattern cross at right angles mutually, respectively, When there are more rates that have the 2nd element that has periodicity in the direction which intersects said 2-way, and said 1st element occupies on said mask than a rate that said 2nd element occupies, While setting the 1st surface of light source as each of four fields which carries out eccentricity and is mutually located symmetrically from an optic axis of said illumination-light study system on said Fourier transformation plane or its nearby surface make oblique illumination light corresponding to period directions of said 1st element, So that oblique illumination light corresponding to period directions of said 2nd element may be made Said Fourier transformation plane, Or a projection aligner having had a setting-out component which sets the 2nd surface of light source as each of four fields which carries out eccentricity and is mutually located symmetrically from an optic axis of said illumination-light study system on the nearby surface, and making area of said 1st surface of light source larger than area of said 2nd surface of light source.

[Claim 7]The projection aligner according to claim 6, wherein said setting-out component specifies said 1st and 2nd surfaces of light source with a gobo or a semi transmission board arranged in a Fourier transformation plane of said illumination-light study system, or its nearby surface.

[Claim 8]While entering a projection optical system which projects a pattern including the 1st element that has periodicity in a 2-way which intersects perpendicularly on a mask, and the 2nd element that has periodicity in the different direction from said 2-way on a sensitized substrate, and light from a light source and forming the surface light source, In a projection aligner provided with an illumination-light study system on which light from each point within said surface light source is made to superimpose on said mask, A projection aligner having had a gobo characterized by comprising the following and changing said 1st transparent part and said 2nd transparent part in the area according to importance of said 1st and 2nd elements.
The 1st transparent part of four quadrants specified with said two axes of coordinates when setting up two axes of coordinates corresponding to said 2-way by making the center of said surface light source into the starting point that is alike, respectively and is mostly formed with an identical area.
The 2nd transparent part mostly formed in each four on said two axes of coordinates with an identical area at the equal distance from said starting point.

[Claim 9]The projection aligner according to claim 8 with which said gobo is characterized by being a semi transmission part except said 1st and 2nd transparent parts.

[Claim 10]The projection aligner according to claim 8 or 9 having further a dark filter which attenuates light volume of the diffracted light which occurs from said 2nd element and is distributed over a center section of the pupil surface of said projection optical system.

[Claim 11]In a projection aligner provided with a projection optical system which projects a pattern of a mask on a sensitized substrate, and an illumination-light study system which enters light from a light source, forms the surface light source in an optical Fourier transformation plane to said mask, or its nearby surface, and irradiates said mask with light from said surface light source, When r and a coherence factor of said surface light source are made into a sigma value for a radius of a circle which defined the rectangular coordinate system XY by having made the center of said surface light source into the starting point, and was approximated to an outside of said surface light source, The coefficients a and b, respectively as 0.1 r/sigma<=a <=0.4 r/sigma and 0.4 r/sigma<=b <=0.8 r/sigma, A projection aligner providing a light-intensity-distribution adjusting member which makes light intensity with inside of a field of -a<=X<=a, the inside of a field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or is set to about 0.

[Claim 12]The projection aligner according to claim 11 when the coefficient c is made into 0.3 r/sigma<=c <=0.6 r/sigma, wherein said light-intensity-distribution adjusting member makes light intensity in a field of $X^2+Y^2<=c^2$ smaller than other fields or sets it to about 0 on said surface light source.

[Claim 13]When said illumination-light study system is constituted so that image formation of the starting point of said surface light source may be carried out to the center of a pupil surface of said projection optical system, and a radius on said surface light source of an effectual pupil diameter of said projection optical system is made into r_0, The projection aligner according to claim 11 or 12 making or more into 0.7 said sigma value which is ratio r/r_0 with the radius r of said surface light source.

[Claim 14]The projection aligner according to any one of claims 1 to 13, wherein said pattern is formed by transparent part and a half-tone transparent part.

[Claim 15]In a projection exposure method which projects a pattern image of said mask on a sensitized substrate via a projection optical system while irradiating a mask with illumination light through an illumination-light study system,

While distributing said illumination light in a field of the shape of zona orbicularis of specified width centering on an optic axis on a field which serves as a relation of the Fourier transform optically to a pattern surface side of said mask within said illumination-light study system, or its nearby surface, A projection exposure method distributing said illumination light over two or more discrete fields except the central part by the inside of a field of the shape of said zona orbicularis.
[Claim 16]In a projection exposure method which projects a pattern image of said mask on a sensitized substrate via a projection optical system while irradiating a mask with illumination light through an illumination-light study system,
An optical Fourier transformation plane to a pattern surface side of said mask in said illumination-light study system when irradiating a pattern characterized by comprising the following, Or the 1st field set as each of four quadrants specified according to a rectangular coordinate system corresponding to said 2-way which makes an optic axis the starting point on the nearby surface, And a projection exposure method characterized by changing said 1st field and said 2nd field in the area according to importance of said 1st and 2nd elements while lessening light volume except the 2nd field mostly set up on an axis of coordinates of said rectangular coordinate system at the equal distance from said starting point or making it about 0.
The 1st element that has periodicity in a 2-way which intersects said illumination light perpendicularly on said mask.
The 2nd element that has periodicity in the different direction from said 2-way.

[Claim 17]In a projection exposure method which projects a pattern image of said mask on a sensitized substrate via a projection optical system while irradiating a mask with illumination light through an illumination-light study system,
An optical Fourier transformation plane to a pattern surface side of said mask in said illumination-light study system, Or when r and a coherence factor of said surface light source are made into a sigma value for a radius of a circle which defined the rectangular coordinate system XY by having made into the starting point the center of the surface light source formed in the nearby surface, and was approximated to an outside of said surface light source, The coefficients a and b, respectively as 0.1 r/sigma<=a <=0.4 r/sigma and 0.4 r/sigma<=b <=0.8 r/sigma, A projection exposure method making light volume with inside of a field of -a<=X<=a, the inside of a field of -b<=Y<=b and -a<=Y<=a, and -b<=X<=b smaller than other fields on said surface light source, or making it about 0.
[Claim 18]The projection exposure method according to claim 17 by which making light intensity in a field of $X^{2}+Y^{2}<=c^{2}$ smaller than other fields on said surface light source by making the coefficient c into 0.3 r/sigma<=c <=0.6 r/sigma, or being referred to as about 0.
[Claim 19]The projection exposure method according to any one of claims 1 to 18, wherein said mask is a halftone phase shift mask.
[Claim 20]In a projection exposure method which projects a pattern image of said mask on a sensitized substrate via a projection optical system while irradiating a mask with illumination light through an illumination-light study system,
When irradiating a halftone phase shift mask including the 1st element that has periodicity in a 2-way which intersects said illumination light perpendicularly, and the 2nd element that has periodicity in the different direction from said 2-way, An optical Fourier transformation plane to a pattern surface side of said mask in said illumination-light study system, Or the 1st field set as each of four quadrants specified according to a rectangular coordinate system corresponding to said 2-way which makes an optic axis the starting point on the nearby surface, And a projection exposure method lessening the light volume except two or more 2nd fields mostly set as the equal distance from said starting point corresponding to said 2nd element, or making it about 0.

[Translation done.]

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審査請求　未請求　請求項の数８（全 16 頁）　最終頁に続く

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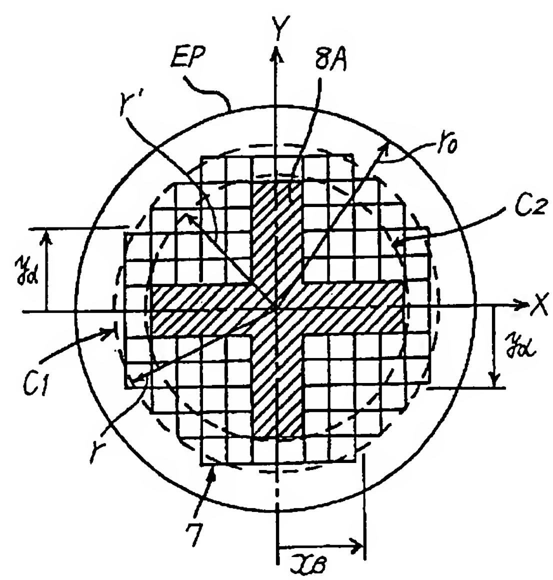
(54)【発明の名称】　投影露光装置

(57)【要約】

【目的】レチクル上の縦横周期パターンとともに斜め周期パターンの焦点深度も改善した変形光源を持つ投影露光装置を得る。

【構成】　４つの開口によって４光源を作る照明系において、コヒーレンスファクターσ値が０．８～０．６４の範囲を輪帯状面光源とし、σ値が０．６４以下の所で十字状遮光部を設けて４つの面光源を作る。



【特許請求の範囲】

【請求項１】　投影すべきパターンが形成されたマスクを照明する照明系と、前記パターンの像を感光基板上に投影する投影光学系とを備えた投影露光装置において、前記照明系は、前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面を内部に有する照明光学系と、前記フーリエ変換面上、もしくはその近傍面上で光軸を中心とした所定半径内に照明光を分布させる光分布設定手段とを含み；該光分布設定手段は前記光軸を中心とした所定幅の輪帯状の領域内に前記照明光を分布させるとともに、該輪帯状の領域の内側の中心部を除く離散的な複数部分の領域に前記照明光を分布させることを特徴とする投影露光装置。

【請求項２】　投影すべきパターンが形成されたマスクに照明光を照射するための光源と、前記マスクのパターン面に対して光学的にフーリエ変換の関係となる面が内部に形成され、該フーリエ変換面、もしくはその近傍面に前記光源の２次光源が作られる照明光学系と、該照明光学系からの照明光によって照射された前記マスクのパターンからの光を入射して、該パターンの像を感光基板上に結像投影する投影光学系とを備えた投影露光装置において、

前記マスク上のパターンが互いに直交する２方向の夫々に周期性を持つ第１のパターン形状と、該２方向の夫々と交差する方向に周期性をもつ第２のパターン形状とで形成され、前記マスク上で前記第１のパターン形状のしめる割合が前記第２のパターン形状のしめる割合よりも多いとき、前記第１のパターンの形状の周期性の方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から所定量だけ偏心して互いに対称的に位置する４つの領域の夫々に第１の光源面を設定する第１設定部材と、

前記第２のパターン形状の周期性の方向に対応した傾斜照明光を作るように、前記フーリエ変換面、もしくはその近傍面上で前記照明光学系の光軸から所定量だけ偏心して互いに対称的に位置する４つの領域の夫々に第２の光源面を設定する第２設定部材とを備え、前記第１の光源面の面積を前記第２の光源面の面積よりも大きくしたことを特徴とする投影露光装置。

【請求項３】　前記第１設定部材と第２設定部材は、前記照明光学系のフーリエ変換面、もしくはその近傍面に配置された遮光板の透過部形状によって規定したことを特徴とする請求項第２項に記載の装置。

【請求項４】　前記照明光学系は前記光源面を作るフライアイレンズを含み、該フライアイレンズの射出面側に前記遮光板を配置したことを特徴とする請求項第３項に記載の装置。

【請求項５】　マスク上で直交する２方向に周期性をもって形成された第１のパターン形状と、それ以外の方向に周期性をもつ第２のパターン形状とを感光基板上に結像投影する投影光学系と、光源からの光を入射して所定半径の円形領域に包含される大きさの光源像を形成するフライアイレンズと、該フライアイレンズによる光源像を前記投影光学系の瞳面、又はその近傍面の中央に結像させるとともに、前記光源像内の各点からの光を前記マスク上で重畳させる集光光学系とを備えた投影露光装置において、

前記光源像の中心を原点として前記パターンの周期性の方向のうち互いに直交する２方向の夫々に対応した２つの座標軸を設定したとき、該２つの座標軸で規定される４つの象限の夫々にほぼ同一面積で形成された第１の透過部と、前記原点からほぼ等距離の位置で前記２つの座標軸上の夫々の４ヶ所に、ほぼ同一面積で形成された第２の透過部とを有する遮光板を前記フライアイレンズの射出側に配置し、前記第１パターン形状と第２パターン形状との重要度に応じて前記遮光板の第１の透過部と第２の透過部との面積を異ならせたことを特徴とする投影露光装置。

【請求項６】　マスクのパターンを感光基板上に結像投影する投影光学系と、光源からの光を入射して、前記マスクに対する光学的なフーリエ変換面、もしくはその近傍面に所定形状の面光源を形成し、該面光源からの光を前記マスク上に一様に照射する照明光学系とを備えた投影露光装置において、

前記面光源の中心を原点として直交座標系ＸＹを定め、前記面光源の外形に近似した円の半径をｒ、前記面光源のコヒーレンスファクターをσ値としたとき、係数ａ、ｂをそれぞれ $0.1r/\sigma \leqq a \leqq 0.4r/\sigma$ 、 $0.4r/\sigma \leqq b \leqq 0.8r/\sigma$ として、前記面光源上で $-a \leqq X \leqq a$、かつ $-b \leqq Y \leqq b$ の領域内と $-a \leqq Y \leqq a$、かつ $-b \leqq X \leqq b$ の領域内との光強度を他の領域よりも小さくするか、もしくはほぼ零にする光強度分布調整部材を設けたことを特徴とする投影露光装置。

【請求項７】　前記光強度分布調整部材は、係数ｃを $0.3r/\sigma \leqq c \leqq 0.6r/\sigma$ としたとき、前記面光源上で、$X^2 + Y^2 \leqq c^2$ の領域内の光強度を他の領域よりも小さくするか、もしくはほぼ零とすることを特徴とする請求項第６項に記載の装置。

【請求項８】　前記照明光学系は前記面光源の原点を前記投影光学系の瞳面の中心に結像するように構成され、該投影光学系の実効的な瞳径の前記面光源上での半径を r_0 としたとき、前記面光源の半径ｒとの比 r/r_0 であるσ値を、０．７以上にしたことを特徴とする請求項第６項又は第７項のいずれか１項に記載の装置

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、半導体集積回路、液晶表示素子等の微細パターンの露光転写に使用される投影露光装置に関し、特に転写すべきパターンの形成されたマスク（レチクル）の照明方法に工夫を施した露光装置

に関する。

【０００２】

【従来の技術】年々微細化が進むリソグラフィ工程においては、現在、６４ＭＤ－ＲＡＭ製造用の実用的な投影露光装置の導入が必須となっている。このような微細なパターンの投影露光転写を十分な精度で達成するために、従来より様々の工夫が提案されている。そのうち、特に転写すべきパターンがライン・アンド・スペース（以下Ｌ＆Ｓとする）のように、ある方向に周期性をもつときに、従来よりも格段に解像力と焦点深度とを拡大させる手法として、特開平４－１０８６１２号公報、特開平４－２２５５１４号公報等のような超解像技術が提案された。

【０００３】この超解像技術は、投影露光すべきＬ＆Ｓパターンが形成されたマスク基板（レチクル）への照明光の配向特性だけを特殊なものにすることで、従来の照明方法では解像しなかった微細なパターンを十分な焦点深度をもって解像させるものである。その照明光の配向特性は照明光学系内のレチクルに対するフーリエ変換面内での照明光束の分布、すなわち２次光源像の分布を、レチクルのＬ＆Ｓのパターンの微細度（ピッチ等）に対応して制御することによって作られる。

【０００４】図１は、上記公報に開示された技術を適用した照明光学系の模式的な構成を示す斜視図である。ここでは照明光源として水銀ランプ１を用い、この水銀ランプ１の発光点を楕円鏡２の第１焦点に配置する。楕円鏡２で反射した照明光ＩＬａは第２焦点３で一度収れんした後、不図示のミラーで反射されてコリメータレンズ系４に入射する。一般に図１のように楕円鏡２と水銀ランプ１とを組み合わせると、照明光ＩＬａの断面は輪帯状（ドーナツ状）の強度分布をもつ。この輪帯状の断面の照明光ＩＬａはコリメータレンズ系４でほぼ平行光束に変換されて、照明系内のフーリエ変換面に配置された遮光板８に達する。遮光板８上には光軸ＡＸから等距離の位置に４つの開口が設けられ、この開口の夫々にはフライアイレンズ７Ａ、７Ｂ、７Ｃ、７Ｄが設けられる。これらフライアイレンズ７Ａ～７Ｄの夫々の入射面は、いずれも輪帯状断面の照明光束ＩＬａ内に位置する。また、フライアイレンズ７Ａ～７Ｄの夫々の射出側には、そのフライアイレンズ内のエレメントレンズの数分だけ、水銀ランプ１の点光源像が形成される。従って、フライアイレンズ７Ａ～７Ｄの各射出面には２次光源像（面光源）が形成される。

【０００５】各フライアイレンズ７Ａ～７Ｄの夫々からの照明光は、コンデンサーレンズ等を含む逆フーリエ変換光学系１１（以後便宜的にコンデンサーレンズと呼ぶ）によって、レチクルＲのパターン形成領域ＰＡ上に一様に重畳して照射される。レチクルＲのパターン領域ＰＡの中心に光軸ＡＸが通るように、レチクルＲを配置し、その中心を座標系ＸＹの原点としたとき、Ｌ＆Ｓ状のレチクルパターンは、多くの場合、Ｘ方向にピッチをもつＬ＆Ｓパターン（縦パターン）ＰｖとＹ方向にピッチをもつＬ＆Ｓパターン（横パターン）Ｐｈとに分けられる。すなわち、パターン領域ＰＡ内にはＸ方向とＹ方向との２方向について周期性をもつパターン群が集合して形成される。

【０００６】Ｌ＆ＳパターンＰｖ、ＰｈのＸ、Ｙ方向のピッチのうち、最小のものに対して照明条件を最適化するものとすると、フライアイレンズ７Ａ～７Ｄの夫々の光軸ＡＸからの偏心量ｙα、ｘβは、そのＬ＆Ｓパターンの最小ピッチと一義的な関係で決められる。例えばＬ＆ＳパターンＰｈのＹ方向の最小ピッチをＧｙ（μｍ）、照明光ＩＬａの波長をλ（μｍ）、コンデンサーレンズ１１からレチクルＲまでの距離、すなわち焦点距離をｆ（ｍｍ）とし、Ｌ＆ＳパターンＰｈから発生する１次回折光の回折角（０次光からの角度）を２θｙ（ｒａｄ）としたとき、着目する１つのフライアイレンズのＹ方向の偏心量ｙαは、$\sin 2\theta y = \lambda / Gy$、$y\alpha = f \cdot \sin\theta y$がほぼ同時に満たされるように決められる。

【０００７】さらに、Ｌ＆ＳパターンＰｖのＸ方向の最小ピッチをＧｘ（μｍ）とし、Ｌ＆ＳパターンＰｖから発生する１次回折光の回折角を２θｘ（ｒａｄ）としたとき、着目する１つのフライアイレンズのＸ方向の偏心量ｘβは、$\sin 2\theta x = \lambda / Gx$、$x\beta = f \sin\theta x$がほぼ同時に満足するように決められる。以上のように、従来の特殊照明法（変形光源）では、レチクルＲ上のＬ＆Ｓパターンのうち、Ｘ方向にピッチを有するパターンＰｖの超解像投影には、フーリエ変換面上でＸ方向に対称的に偏心した２次光源像のペア（フライアイレンズ７Ａと７Ｄ、またはフライアイレンズ７Ｂと７Ｃ）からの傾斜照明光が寄与し、Ｙ方向にピッチを有するパターンＰｈの超解像投影には、フーリエ変換面上でＹ方向に対称的に偏心した２次光源像のペア（フライアイレンズ７Ａと７Ｂ、またはフライアイレンズ７Ｃと７Ｄ）からの傾斜照明光が寄与する。

【０００８】尚、図１において第２焦点３には露光の開始と中断とを制御するロータリーシャッター等が配置され、第２焦点３はフライアイレンズ７Ａ～７Ｄの夫々の射出面側に形成される２次光源像と共役であり、フライアイレンズ７Ａ～７Ｄの夫々の入射面はレチクルＲのパターン面と共役になっている。

【０００９】

【発明が解決しようとする課題】上記の如き従来技術においては、転写すべき回路原版（レチクル）の特定の方向、例えば直交する２方向の周期パターンについてのみ解像度や焦点深度を改善する効果がある。ところが、他の方向、特に上記の直交する２方向の夫々に対して４５°回転した方向に周期性をもつパターンについては、通常の照明法を適用した露光装置よりも解像度や焦点深度が低下するという問題があった。

【0010】本発明は、このような問題に鑑みて成されたものであり、レチクル上の、特にレチクル外形と平行な縦横方向の夫々に周期性を有する2方向パターンの解像度と焦点深度を大幅に向上させつつ、これらとは方向の異なる斜め（例えば45°回転）パターンについても、通常の装置より高解像かつ大焦点深度が得られる投影露光装置の提供を目的としている。

【0011】

【課題を解決するための手段】本発明においては、投影露光装置のマスク照明用の照明光学系内のフーリエ変換面に形成される光源像（面光源）の2次元的な形状を、従来の形状に加えて若干変形するようにした。具体的には、図2に示すように、ほぼ円形の領域C1内に包含される面光源（ここではフライアイレンズ7の射出面）のうち、原点から所定半径の円C2よりも外側の輪帯部分は全く遮光しないようにする。そして、円C2の内側に原点からX、Y方向の夫々に延びた十字状遮光部8Aを設け、X、Y座標軸で規定された4つの象限の夫々に、互いに分離した透過部（光源面）を形成するようにした。その4つの象限の透過部は従来と同様にX、Y方向の夫々にピッチを有する周期性パターンの超解像に寄与する。

【0012】従来においては十字状遮光部8Aの4つの先端部が全て面光源の半径（ほぼ円C1の半径）以上に延設されていたが、本発明では十字状遮光部8の4つの先端部を面光源の半径よりも小さくし、それら4つの先端部の外側にも、面積的に小さな面光源が存在するようにした。尚、この図2中の直交座標系XYの設定は、図1のものと全く同じであり、座標系XYの原点は照明光学系、あるいは投影光学系の光軸AXと一致している。また、図2においてEPは、2次元光源像（面光源）としてのフライアイレンズ7の射出面内で見た投影光学系の瞳面を表す。

【0013】一般にこの種の投影露光装置では、投影光学系の瞳面（フーリエ変換面）内に面光源像（フライアイレンズ7の射出面の像）が形成されるようになっている。そして照明光学系内のフーリエ変換面上で見た投影光学系の瞳EPの半径r_0と、面光源の半径rとの比r/r_0のことはσ値と呼ばれる。そこで、図2において円C1の半径をσ値で0．7～0．8程度、円C2の半径r'を$0.64r_0=0.64r/\sigma$程度にしておくと、X、Y方向の夫々に対して45°だけ回転した方向にピッチを有する0．4～0．45μmの線幅の周期パターンに対しても超解像の効果が十分に得られるようになる。尚、図2に示した円C1、C2の設定条件や十字状遮光部8Aの寸法条件については、以後の実施例において詳細に例示する。

【0014】

【作用】本発明においては、いわゆる変形光源の光源形状として、レチクル上の縦横パターンに最適化された部分を多く含みながら、かつ、斜めパターンについても最適な部分（図2の十字状遮光部8Aの先端の外側）も、わずかに含ませるようにした。このため、従来の変形光源ではむしろ通常照明より悪化してしまっていた斜めパターンの解像度及び焦点深度も、通常照明に比べて改善することができる。また、縦横パターンに最適化された光源部の面積（光量）と、斜めパターンに最適化された光源部の面積（光量）のバランスも最適化されているために、縦横パターンの投影時の解像度や焦点深度の改善も従来の変形光源形状の場合とほぼ同程度に実現できる。尚、図2のように十字状遮光部8Aの外側に輪帯状の面光源部（半径r'～r）を設けた場合、斜めパターンの周期性の方向はX、Y方向の夫々に対して必ずしも45°（又は135°）でなくても、本発明の効果が得られる。

【0015】

【実施例】図3は本発明の実施例による投影露光装置の全体的な概略構成を示す図である。そして、図3中の部材で、図1中のものと同じ機能のものには同一の符号を付してある。水銀ランプ1からの照明光ILaは楕円鏡2で第2焦点3に収れんされたのち、コリメータレンズ系4、ミラー5、インプット側フィールドレンズ6を介してフライアイレンズ7に入射する。第2焦点3の位置には一方向に回転するロータリーシャッター19Aが配置され、シャッター19Aは駆動ユニット（モータ、駆動回路等）19Bによって制御される。また、照明光ILaはフライアイレンズ7に入射する際、図1の場合と同様に輪帯状の強度分布をもつが、それはフライアイレンズ7の射出側に設ける遮光板（絞り）8の形状が、図2のような変形光源を作るものの場合に適している。しかしながら、遮光板8を従来と同様の円形開口絞りをもつ遮光板9に切り換えて通常照明を行う場合、照明光ILaの輪帯状の強度分布はあまり好ましくない。特にレチクルRが位相シフト法を適用したものの場合、レチクルRへの照明光の開口数は比較的小さな値（σ値で0．2～0．4程度）に絞られる。その場合、フライアイレンズ7の中央部分のエレメントレンズからの照明光、すなわち照明光ILaの輪帯状の強度分布の中央部の光のみがレチクル照明に利用されることになり、照度低下を招くことになる。

【0016】そこで通常照明に切り替えるときは、例えばUSP. 4,637,691等に開示されているようなプリズム30を、コリメータレンズ4とフィールドレンズ6との間に交換可能に配置し、照明光ILaの輪帯状の強度分布を円形状の分布に整形するとよい。さて、フライアイレンズ7の射出側には、図2のような変形光源用の遮光板8や通常光源用の遮光板9を交換可能に保持するターレット10が設けられる。ターレット10は駆動ユニット10Aによって、所定角度毎に回転させられる。図3では遮光板8がフライアイレンズ7の射出側に位置決め

されている。こうして遮光板８の透過部を通った照明光ＩＬｂはアウトプット側フィールドレンズ１３、ミラー１２を介してコンデンサーレンズ１１に入射する。フライアイレンズ7中の選ばれた複数のエレメントレンズの夫々の点光源からの光は、コンデンサーレンズ１１によって全てレチクルRのパターン領域上で重畳して一様に照射される。図3中に示した照明光ＩＬａは、選ばれた1つのエレメントレンズの点光源からの光を代表して表したものである。

【００１７】ここで、遮光板８の遮光部形状とフライアイレンズ7のエレメントレンズ配置との関係は、図2に示したものと同じであり、現実的には図２中の円Ｃ１の外側も遮光部とし、十字状遮光部８Ａも含めて石英板等の透過板の上に金属層等を蒸着して作る。また、フライアイレンズ7の射出面（もしくは遮光板8の面）は、レチクルRのパターン面に対して光学的なフーリエ変換の関係になっている。従ってフライアイレンズ7の１つのエレメントレンズで作られた点光源からの光は、コンデンサーレンズ１１によって入射角θの平行光束となってレチクルRを傾斜照明する。このとき、１つの点光源のフーリエ変換面上での偏心量（光軸ＡＸからの距離）は、入射角θの正弦（$\sin\theta$）と比例関係にある。この入射角θは、レチクルR上の周期的なパターンのピッチに応じて適量値が存在する。Ｘ、Ｙ方向の夫々に周期的なパターンに対する偏心量$y\alpha$、$x\beta$の決定方法については、先の特開平４－２２５５１４号公報等に開示されているので、ここではその説明を省略する。

【００１８】照明光ＩＬｂの照射によって、レチクルR上の特定ピッチの周期パターンから発生した各回折光のうち、0次回折光D_0と1つの1次回折光D_1とは、両側テレセントリックな投影光学系ＰＬの瞳ＥＰ内で対称的に分布した後、ウェハWに達する。従ってレチクルR上の特定ピッチの周期パターンは、1つの1次回折光D_1と0次回折光D_0との干渉によって作られる明暗像としてウェハW上に結像される。ウェハWの表面にはレジスト層が塗布されているので、シャッター１９Ａの開時間を制御して、そのレジストに見合った最適露光光量を与えると、レチクルRの周期パターンの縮小像がレジスト層に形成される。

【００１９】そのウェハWは、光軸ＡＸと垂直な面内で２次元移動するステージWＳＴ上に載置され、ステージWＳＴはレーザー干渉計１８Ａによる座標位置の計測結果に基づいて、モータ等の駆動ユニット１８Ｂにより駆動される。制御ユニット２０は、そのウェハステージWＳＴ、シャッター用駆動ユニット１９Ｂ、ターレット用駆動ユニット１０Ａを統括的に制御する。特にターレット用駆動ユニット１０Ａに対しては、レチクルRの登録名による自動制御、またはオペレータからの指示による手動制御が可能となっている。

【００２０】図4は第1の実施例による遮光板8の具体的な形状を示す平面図であり、図5は図４中の座標系ＸＹと同一の座標系で見たときのレチクルR上の周期パターン配置を模式的に示したものである。図5に示したように、レチクルR上にはレチクルの外形各辺の方向Ｘ、Ｙと平行な周期的な縦パターンＰｖ（ピッチはX方向）と横パターンＰｈ（ピッチはY方向）とが多く存在し、それらにくらべて割合としては少ないが、Ｘ、Ｙ方向の夫々に対して４５°（又は、１３５°）回転した周期的な斜めパターンＴａ、Ｔｂも存在する。このようなパターンの構成は、本実施例に限らず、半導体デバイス用の回路原版としてのレチクルでは普通のことであり、縦パターンＰｖ、横パターンＰｈの割合は多く、斜めパターンＴａ、Ｔｂの割合は少ないのが一般的である。

【００２１】これらのパターンを有するレチクルRに対して、図4に示した遮光板8を適用した照明光学系からの照明光を照射すると、幅２ａ、長さ２ｂの十字状遮光部8Ａによって区画された４つの扇状透明部８１ａ、８１ｂ、８１ｃ、８１ｄの夫々を面光源として、レチクルR上の縦パターンＰｖと横パターンＰｈとの投影時の解像度や焦点深度が従来と同様に向上する。ここで、遮光板8は最外周に外径値r_0、内径ｒの輪帯遮光部８Ｂを有し、原点（光軸ＡＸの通る点）から十字状遮光部８Ａの先端までの長さｂは、ｒ＞ｂの関係に設定されている。尚、輪帯遮光部８Ｂの内径エッジが図２中の円Ｃ１に相当し、輪帯遮光部８Ｂの外径値r_0が投影光学系ＰＬの瞳ＥＰの実効的な最大径（すなわち最大開口数N.A.）に対応するものとすると、輪帯遮光部８Ｂの内径値ｒと外径値r_0との比r/r_0は、コヒーレンスファクターのσ値に他ならない。

【００２２】さらに、図4の遮光板8において、十字状遮光部8ＡのＸ、Ｙ方向の各先端部には、斜めパターンＴａ、Ｔｂの結像に有効な透明部８１ｅ、８１ｆ、８１ｇ、８１ｈが形成されている。従来のこの種の照明方法では、その４つの透明部８１ｅ、８１ｆ、８１ｇ、８１ｈは全て遮光部とされていた。この４つの透明部８１ｅ～８１ｈの夫々に光源像（面光源）を作ると、縦パターンＰｖや横パターンＰｈの投影時の解像度や焦点深度を多少劣化させる副作用がある。しかしながら、縦パターンＰｖ、横パターンＰｈに対して有効な扇状透明部８１ａ～８１ｄの個々の面積（あるいは光量）に比べて、４つの透明部８１ｅ～８１ｈの個々の面積（あるいは光量）は十分に小さいため、縦パターンＰｖや横パターンＰｈについての投影性能を大きく損なうものとはならない。

【００２３】ここで遮光板8の各値ｒ（σ）、ａ、ｂの関係は、$0.1r/\sigma \leq a \leq 0.4r/\sigma$、$0.4r/\sigma \leq b \leq 0.8r/\sigma$程度に定められる。値ａが$0.1r/\sigma$（すなわち$0.1r_0$）よりも小さくなると、変形光源としての効果が消失し、通常照明（光軸ＡＸを中心とする単なる円形又は多角形面光源）と何ら変わらなくなる。さら

に、値aが 0.4r／σ（すなわち 0.4r_0 ）よりも大きくなると、４つの扇状透明部８１a～８１dの夫々の面積上の重心点が、遮光板８の原点から大きく離れた所に出来るため、レチクルR上のパターンＰｖ、Ｐｈのうちピッチがより微細になったものに対しては照明光の傾斜角の最適化がはかられるが、それよりもピッチが粗くなったパターンに対しては最適化がはかられず、焦点深度の拡大効果が得られにくくなる。

【００２４】また値bについても、 0.4r／σより小さいと縦パターンＰｖ、横パターンＰｈの解像に不適当な面光源、すなわち透明部８１ｅ～８１ｈの面積が増大するため、縦横パターンＰｖ、Ｐｈの投影時の焦点深度が著しく減少してくることになる。逆に値bが 0.8r／σより大きくなると、斜めパターンＴａ、Ｔｂの投影時の解像度や焦点深度の改善効果が薄らいでしまう。

【００２５】また図４に示した遮光板８の形状では、わずかながらも斜めパターンＴａ、Ｔｂの結像に有効な面光源部を含んでおり、かつ中央の十字状遮光部８Ａの大部分は縦パターンＰｖ、横パターンＰｈのみでなく、斜めパターンＴａ、Ｔｂに対しても不適当な面光源部をも遮光している。このため斜めパターンＴａ、Ｔｂの結像においても、従来の通常照明（光軸ＡＸを中心とする単なる円形又は多角形面光源）よりは格段に高い解像度や焦点深度を得ることができる。

【００２６】さて、図６は遮光板８の第２実施例による形状を示し、図４の遮光板８の構成と同じ部分には同一の符号を付けてある。本実施例は基本的には図４の遮光板と同じであるが、中央の十字状遮光部８Ａ’の中心に半径r_c （r_c ＞a）の円形遮光部を設けた点が異なる。このように面光源の中心部を円形遮光部で遮へいすると、縦パターンＰｖ、横パターンＰｈの結像に関して特に有効な光源部、すなわち４つの扇状透明部８１a～８１dの夫々の面積が図４の場合よりも少なくなり、相対的に斜めパターンＴａ、Ｔｂの結像に関して有効な光源部、すなわち４つの透明部８１ｅ～８１ｈの夫々の面積の割合が増大する。この為、斜めパターンＴａ、Ｔｂの結像時の解像度や焦点深度を図４の場合よりもさらに改善することができる。

【００２７】また図６の遮光板８によって新たに遮光される部分は、比較的に光軸ＡＸに近い位置であり、やや粗め（例えばウェハ上での線幅が０．５μm以上）のピッチの縦パターンＰｖ、横パターンＰｈの結像時に焦点深度を改善する効果はあるものの、より微細なピッチの縦、横パターンＰｖ、Ｐｈに対しては解像度や焦点深度を改善する効果があまりない。そのため、投影露光すべきレチクルR上のL＆Sパターンが、比較的微細なピッチのものに限られていて、かつ同程度のピッチの斜めパターンも、少ないながらも適度の割合で含まれている場合、図６の遮光板８を用いた縦、横パターンＰｖ、Ｐｈの総合的な結像性能は、図４の遮光板８を用いたときと比べて特に劣化することはない。

【００２８】ここで図６の遮光板８の中央の円形遮光部の半径ｒ２は、 0.3r／σ≦ｒ２≦0.4r／σ程度に定められ、厳密にはa＜ｒ２＜bの条件も加味される。ここで半径ｒ２の値が小さくなって結局、a≧ｒ２となると、図４の遮光板８の形状と何ら変わらなくなってしまうため、斜めパターンＴａ、Ｔｂの結像時の焦点深度拡大作用はやや減少することになる。逆に半径ｒ２の値を大きくしていくと、その面光源形状は輪帯に近づくため、縦、横パターンＰｖ、Ｐｈの結像時の焦点深度拡大作用が減少してしまう。

【００２９】図７は遮光板８の第３実施例による形状を示し、基本的には図４の遮光板８の形状と同じであるが、外周の輪帯状遮光部８Ｂの内側で、４つの扇状透過部８１a～８１dの夫々の一部に９０°のコーナをもつ微少遮光部８Ｃ、８Ｄを設けた点が異なる。これら微少遮光部８Ｃ、８DはX軸、Y軸の夫々と平行なエッジを有し、X軸からY方向に距離ｄｙだけ離れており、Y軸と平行エッジはY軸からX方向に距離ｄｘだけ離れている。その微少遮光部８Ｃ、８Dは扇状遮光部８１a～８１dの夫々の中で、X軸、Y軸の夫々から最も遠い部分に設けられており、この遮光部８Ｃ、８Dの部分からの照明光束は縦パターンＰｖ、横パターンＰｈとして最もピッチが小さいもの、あるいは微細なピッチの斜めパターンに対して最適化された配向特性を持つ。このため、そのように最もピッチが小さい縦、横パターン、あるいは微細な斜めパターンの結像時に、焦点深度拡大作用が得られる。ところが遮光部８Ｃ、８Dの部分から照明光束は、中程度（例えば０．４～０．５μmの線幅）の微細度のL＆Sパターンの結像時に、むしろ焦点深度を減少させる方向に作用してしまう。

【００３０】従って図７の遮光板８は、ここでの変形光源方式によって理論上結像可能な最小ピッチ程度に微細な縦横パターンは含まないが、それよりも粗い中程度の微細度のL＆Sパターンを含むレチクルRを投影露光するのに適していると言える。尚、図７から明らかなように、微少遮光部８Ｃ、８Dのエッジの距離ｄｘ、ｄｙは、ここではｄｘ＜ｒ、ｄｙ＜ｒに定められ、レチクル上の縦パターン、横パターン、斜めパターンの各ピッチがほぼ同程度であれば、さらにｄｘ＝ｄｙに定められる。そして図７の遮光板８内の扇状透明部８１a～８１dの夫々の面積的な重心点（光量重心点）の位置は、微少遮光部８Ｃ、８Dが存在しないときの重心点位置とそれ程変化していない。また微少遮光部８Ｃ、８Dの各エッジのX、Y軸からの距離ｄｘ、ｄｙを小さくしていくと、各扇状透明部８１a～８１dは矩形（又は正方形）に近づいていく。

【００３１】図８は、微少遮光部８Ｃ、８Dの各エッジのX、Y軸からの距離ｄｘ、ｄｙを比較的小さくするとともに、十字状遮光部８Ａ、輪帯状遮光部８Ｂ、微少遮

光部８Ｃ、８Ｄの夫々のエッジをフライアイレンズ７のエレメントレンズの断面形状（ここでは正方形とする）に合わせた場合の遮光板８の形状を示す。尚、先の図４、図６、７の各遮光板の場合も遮光部エッジはエレメントレンズの断面形状に合わせるのが好ましい。図８において、斜めパターンＴａ、Ｔｂの結像時に有効な光源部分を形成する４つの透明部８１ｅ～８１ｈ夫々には、２個のエレメントレンズがＸ軸、Ｙ軸をはさんで位置する。また、十字状遮光部８Ａの幅の半値ａはエレメントレンズの１個分の寸法に定められ、長さｂは５個分の寸法に定められている。そして扇状透明部８１ａ～８１ｄの夫々には、４×４個のエレメントレンズの集合から最外角の１個のエレメントレンズを取り除いたものが位置する。尚、微少遮光部８Ｃ、８Ｄに相当する部分は、それぞれ２個のエレメントレンズを遮へいしている。また、この図の遮光板８の場合、４つの扇状透明部８１ａ～８１ｄと透明部８１ｅ～８１ｈとは、今までの各実施例のようにつながっておらず、互いに独立したものとなっている。さらに４つの扇状透明部８１ａ～８１ｄの夫々の最内角（最も原点に近い隅）に位置する１個のエレメントレンズを遮へいするように、すなわち中心部に４×４個のエレメントレンズの集合体の大きさと同じ正方形（又は矩形）の遮光部を付加してもよい。このような正方形の遮光部の付加によって、先の図６に示した第２の実施例の遮光板８と同様の作用、効果を得ることができる。この場合、中心の四角形遮光部の各辺のエッジのＸ軸、Ｙ軸からの距離は、図６の円形遮光部の半径Ｃと同程度の範囲に定められる。

【００３２】さらに図８中に示した扇状透明部８１ａ～８１ｄの夫々に位置するフライアイレンズ７のエレメントレンズ群は、全てＸ軸、及びＹ軸に対して対称な配置になっている。このような対称配置を採ることによって、レチクル上のＬ＆Ｓパターンの投影像のテレセン誤差（ベストフォーカス面からウェハ面がわずかにずれたときの像の横ずれ）が皆無となる。

【００３３】ここで図９を参照して、図４、図６～８の遮光板８を用いたとき、レチクルＲから発生して投影光学系ＰＬに入射した結像光束の瞳面ＥＰ内での分布について説明する。図９は図２に対応して表したもので、所定のピッチの縦、横パターンＰｖ、Ｐｈに対して最適化された４つの扇状面光源部の光量重心点８０Ａ、８０Ｂ、８０Ｃ、８０Ｄと、その縦、横パターンＰｖ、Ｐｈと同一のピッチの斜めパターンＴａに対して最適化された４つの光量重心点のうちの代表的な１つの重心点８０Ｅとを、瞳面ＥＰ上で示したものである。４つの重心点８０Ａ～８０Ｄの夫々は、各実施例中の４つの扇状透明部８１ａ～８１ｄの夫々の面積的な重心とほぼ一致しており、重心点８０Ｅは透明部８１ｅの面積的な重心点とほぼ一致している。まず、４つの重心点８０Ａ～８０Ｄは、対象となる縦、横パターンのピッチに対して最適化されているので、例えばレチクルＲからの結像光束のうち、重心点８０Ａを通る照明光線の照射によって縦、横パターンから発生する０次光は、重心点８０Ａを通り、±１次回折光の一方は、Ｘ軸、Ｙ軸の夫々と対称に位置する重心点８０Ｂ、８０Ｄを重畳して通る。

【００３４】一方、重心点８０Ｅを通るように配向された照明光線によって縦パターンＰｖから発生する±１次回折光$\pm Dx_1$（回折光束の重心）は、重心点８０Ｅを通りＸ軸と平行な線上に分布するが、その位置は図９のように瞳面ＥＰの最大径の外側になってしまうので、縦パターンＰｖの結像には影響を与えない。ところが横パターンＰｈから発生する１つの１次回折光$-Dy_1$（回折光束の重心）は瞳ＥＰ内のＹ軸上に分布するため、横パターンＰｈの結像に影響を与える。この１次回折光$-Dy_1$は横パターンＰｈの変形照明法による理想的な分布位置とは異なるため、横パターンＰｈの結像にとってはあまり好ましくない光である。しかしながら、重心点８０Ｅを作る照明光量は、小さな面積の透明部８１ｅで決まり、他の４つの重心点８０Ａ～８０Ｄの照明光量に比べて格段に小さい。その比は例えば図８の場合、フライアイレンズ７のエレメントレンズの数の比で決まり、そのため、好ましくない１次回折光$-Dy_1$の光量自体も格段に小さく、横パターンＰｈの結像性能を実用上大きく劣化させることはない。

【００３５】次に斜めパターンＴａ（４５°）からの結像光束の分布について考えてみる。ここでは、代表して重心点８０Ｂを０次光が通るように配向された照明光（扇状透明部８１ｂの透過部）の照射によって斜めパターンＴａから発生する回折光について述べる。斜めパターンＴａのピッチが縦、横パターンＰｖ、Ｐｈのピッチと同程度であるとすると、斜めパターンＴａからの１次回折光$-Dt_1$（回折光束の重心）は、重心点８０Ｂを中心とした半径$2y\alpha$（あるいは$2x\beta$）の円上で、かつ重心点８０Ｂと８０Ｂとを光軸ＡＸを通って結ぶ線（１３５°）上に位置する。この１次回折光$-Dt_1$は、２つの重心点８０Ａ、８０Ｃを結ぶ４５°の線に関して、重心点８０Ｂを通る０次光束と対称的な関係になっていないために、斜めパターンＴａの結像に対しては好ましくない光になっている。

【００３６】ところが、重心点８０Ｅに斜めパターンＴａからの０次光が位置するように，、遮光板８に透明部８１ｅが設けられているので、透明部８１ｅからの照明光によって斜めパターンＴａから発生した１次回折光$-Dt_1'$は、重心点８０Ｅを中心とした半径$2y\alpha$（あるいは$2x\beta$）の円上で、かつ重心点８０Ｅを通る１３５°の線（重心点８０Ｂと８０Ｄを結ぶ線と平行）上に位置する。その重心点８０Ｅと１次回折光$-Dt_1'$との位置関係は、重心点８０Ａと８０Ｃとを結ぶ４５°の線（斜めパターンＴａのフーリエ変換像における中心軸）に対してほぼ対称になっている。従って、透明部８

１ｅからの照明光は、斜めパターンＴａの結像に対して有効な成分になり、斜めパターンの解像度や焦点深度を改善する方向に働く。尚、図９の場合、重心点８０Ｅを０次光とする斜めパターンＴａからの１次回折光－Dt_1’はほぼＸ軸上に位置し、さらにその位置は遮光板８の斜めパターン用の他の透明部８１ｈからの照明光の重心点（８０Ｈとする）に接近している。このように、１次回折光－Dt_1’の位置に透明部８１ｈの重心点８０Ｈが位置することは、斜めパターンＴａがそのピッチ方向に対称的に傾斜した２つの照明光束で照明されることを意味する。

【００３７】以上のことから、投影露光すべき縦、横パターンＰｖ、Ｐｈ、斜めパターンＴａ、Ｔｂの各ピッチが１枚のレチクル上で同程度とすると、斜めパターン用に付加した面光源部（透明部８１ｅ～８１ｈ）の夫々の光量重心点は、理想的にはＸ軸、Ｙ軸上で原点から、$\sqrt{(x\beta^2 + y\alpha^2)}$の距離の所に配置すればよい。この関係は理想的な条件であって、現実的にはその関係から若干（例えば２０％～３０％程度）はずれていても、本発明の効果はそれなりに得られる。

【００３８】図１０は本発明の第４の実施例による照明光学系の部分構成を示し、ここでは図３に示したフライアイレンズ７の部分を、特公平３－７８６０７号公報に開示されているような２連のフライアイレンズ系に変更する。　図３中のコリメータレンズ４とプリズム３０とを通った照明光ＩＬａは、図１０のように１段目のフライアイレンズ７Ｅに入射する。このフライアイレンズ７ＥはＸ、Ｙ方向に４個ずつのエレメントレンズを束ねたものとする。フライアイレンズ７Ｅの各エレメントレンズの射出端に結像した点光源像の夫々からの照明光は、レンズ系２５を介して２段目のフライアイレンズ７Ｆの入射面の全面を重畳して照射する。２段目のフライアイレンズ７Ｆは６×６個の配列でエレメントレンズを束ねたもので、各エレメントレンズの射出面から数ｍｍ程度離れた空間中に３次元光源像（点光源）が結像される。この２連フライアイレンズ系の場合、２段目のフライアイレンズ７Ｆの個々のエレメントレンズの射出側には、１段目のフライアイレンズ７Ｅの射出面に形成された４×４個の点光源像が形成されるので、３次元光源像は１６×３６個の点光源が２次元的に集合した面光源となる。

【００３９】さて、本実施例の場合、図４、図６～８に示した遮光板８は、２段目のフライアイレンズ７Ｆの射出側で、３次元光源像が形成される空間中の面内に配置される。図１１はフライアイレンズ７Ｆの射出側に形成された３次元光源像と遮光板８の遮光部８Ａ（８Ａ’）、８Ｂの各エッジとの配置関係を示したものである。図１１に示すように、フライアイレンズ７Ｆの１つのエレメントレンズの射出側には、４×４個の点光源ＳＰがＸ、Ｙ方向にほぼ等ピッチで整列している。このとき、十字状遮光部８Ａ（８Ａ’）の外形エッジや周辺の輪帯状遮光部８Ｂの内径円Ｃ１に対応するエッジは、全て３次元光源像を形成する点光源のピッチに合わせて屈曲される。すなわち、単一のフライアイレンズ系のときは図８に示したようにフライアイレンズのエレメントレンズの断面形状に合わせて各遮光部のエッジを規定する必要があったが、２連（タンデム）フライアイレンズ系では、そのような必要がない。しかも３次元光源像を形成する点光源の数は、単一フライアイレンズ系の場合よりも格段に増えているため、面光源としての平均的な照度分布は極めて平坦になる。

【００４０】図１２は本発明の第５の実施例によせる照明系の構成を示し、ここでは特開平４－２２５５１４号公報に開示されているように、照明系内のフーリエ変換面上のＸＹ座標系で４つの象限の夫々に位置する縦横パターン用の面光源を、それぞれ独立したフライアイレンズ７０Ａ、７０Ｂ、７０Ｃ、７０Ｄで構成する。そしてコリメータレンズ４からの輪帯状分布の照明光束を四角錐プリズム２６で４つの光束に分割し、それぞれを４つのフライアイレンズ７０Ａ～７０Ｄへ入射する。また、斜めパターン用の面光源は、４本のオプチカルファイバー９０の先端部７０Ｅ、７０Ｆ、７０Ｇ、７０Ｈで構成し、その４本のオプチカルファイバー９０の他端（入射端）側は１本に束ねられ、シャッター１９Ａの後で分岐された照明光の一部がその入射端に集光される。

【００４１】本実施例では斜めパターン用の面光源を作る系が、縦横パターン用の面光源を作る系と独立しているので、投影対象となったレチクル上に斜めパターンが全く存在していないときは、オプチカルファイバー９０の入射端側の光路中に別のシャッターや減光フィルター（ＮＤフィルター）を挿入して、先端部７０Ｅ～７０Ｈの発光を禁止するか、大幅に光量低下させることができる。さらに、そのＮＤフィルターの減光率の調整等によって先端部７０Ｅ～７０Ｈの発光強度を変化させることができるので、レチクルＲ上のＬ＆Ｓパターンのうち斜めパターンがしめる割合に応じて最適な光量を与えることができる。従って、オペレータがレチクルＲ上の斜めパターンの割合に関する情報を、図３中の主制御ユニット２０に入力する構成にしておけば、４つの先端部７０Ｅ～７０Ｈの発光強度を、予め定められたテーブルに従って自動的に最適値（零も含む）に調整することもできる。　また、図１２に示したように、４つのフライアイレンズ７０Ａ～７０Ｄ、４つの先端部７０Ｅ～７０Ｈが独立に設けられるから、レチクルＲ上のＬ＆Ｓのパターンのピッチに応じて、個々のフライアイレンズ、または先端部をＸＹ面内で２次元、または１次元に可動にしておいてもよい。その場合、縦横パターン、斜めパターンのピッチが同程度であり、４つのフライアイレンズ７０Ａ～７０Ｄの夫々の射出側の面光源の光量重心点が、ＸＹ面内で光軸ＡＸを中心とする正方形の４隅に対応した

配置をとるときは、4つのフライアイレンズ70A～70Dの光量重心点の光軸AXからの偏心量と、先端部70E～70Hの光量重心点の光軸からの偏心量とがほぼ等しくなるような関係で可動にするとよい。

【0042】尚、図12の構成において、4つのフライアイレンズ70A～70Dの夫々は、図10と同様にタンデム・フライアイレンズ系としてもよく、また各フライアイレンズ70A～70Dの夫々の射出側に個別に絞り（遮光板）を設け、4つの面光源のそれぞれの大きさを個別に、又は連動して変えられるようにしてもよい。ところで図12において、フライアイレンズ70A～70Dの夫々の間には、特別に遮光板等を設けていないが、各フライアイレンズの間の空間を通ってくる迷光が無視できない程に多いときは、簡単な遮光板（十字状）を設けるのが望ましい。従ってその迷光成分が十分に小さければ、特別に遮光板を設ける必要はない。このことは、先の図4、図6～8に示した遮光板8に対しても同様に適用できることであって、十字状遮光部8A、8A'や輪帯状遮光部8B等を完全な遮光層にしなくてもよいことを意味する。例えば遮光板8上の各遮光部を、露光用の照明光の波長（i線では365nm、KrFエキシマレーザでは248nm）において90%以上の減光率をもつ誘電体薄膜等で構成してもよい。

【0043】さて、ここで以下のシミュレーションの説明のために、これまでに発表されている従来の変形光源の絞り形状の例を図13、14に示す。図13は特定のピッチを有する縦パターンPv、横パターンPhに最適化された中心位置（xβ、yα）と、適当な半径（σ値で0．1～0．3）を有する円形4光源用の遮光板の例である。図14は図13の円形開口の代わりに夫々正方形の開口とし、かつそれら4つの正方形開口の周辺の一部が照明光学系のσ値に相当する半径rより大きい扇状4光源用の遮光板の例である。

【0044】一例として、図14に示す光源形状を用いた縦横L&Sパターン、及び斜め（45°または135°方向）L&Sパターンの投影時に得られるL&Sパターン像のライン、又はスペースの線幅サイズ〔μm〕に対する焦点深度DOF〔μm〕のシミュレーション結果を図15に示す。ここでシミュレーションの条件は、波長λをi線の0．365〔μm〕、投影光学系PLのウェハ側の開口数 N.A. を0．50（レチクル側では0．1）、遮光板8の輪帯状遮光部8Bの内径rをσ値（r/r_0）として0．8（通常の円形面光源のσ値も0．8とする）、十字状遮光部の幅の半値aを開口数換算で0．28、すなわち$a=0.28r/\sigma=0.35r$とした（通常照明では$a=0$で十字状遮光部なし）。ここで焦点深度（DOF）の値は、1：1ラインアンドスペース（L／S）パターン像のコントラストが60%以上になる範囲（全幅）から、パターンニングすべきレジストの厚さ1．2μm、その屈折率1．7によって決まる一定値、1．2／1．7≒0．706〔μm〕を差し引いた値とした。図15中で2点鎖線で表したシミュレーション結果の特性DV1は、図14の従来の遮光板を用いたときの縦、横L&Sパターンに対する焦点深度特性を示し、破線のシミュレーション特性DO1は、同様に図14の遮光板を用いたときの斜め（45°、135°）L&Sパターンに対する焦点深度特性を示す。図14の如き従来の変形光源形状では、斜めパターンに対する焦点深度特性DO1が、比較のためにシュミレートした通常の円形面光源を用いたときの斜めパターンに対する焦点深度特性DCよりわずかに劣る結果となる。尚、通常の円形光源形状の場合は縦、横、斜めパターンのいずれに対しても焦点深度特性DCになる。

【0045】図16は本発明の第1実施例（図4）による遮光板8を用いたときの焦点深度特性のシミュレーション結果を示す。このとき、図4中の十字状遮光部8Aの幅の半値aは$a=0.28r_0=0.35r$に定められ、長さの半値bは$b=0.56r_0=0.7r$とし、露光波長λ、N.A.、σは図15の場合と同じにした。この条件での縦横の1：1のL&Sパターンでの焦点深度特性DV2は、図15中の従来の変形光源（図14）による特性DV1よりわずかに劣るが、一方斜めL&Sパターンに対する焦点深度特性DO2は、通常の円形面光源を用いたときの焦点深度特性DCより上まわっており、本発明の効果が確認されている。また、縦横パターンに対する焦点深度特性DV2も十分にあり、変形光源が本質的に持つ能力を損なうものではない。尚、本シミュレーションでは、十字状遮光部の幅の半値aと長さの半値bをそれぞれ$a=0.28r_0$（投影光学系の開口数N.A.の0．28倍）、$b=0.56r_0$（開口数 N.A.の0．56倍）としたが、これらの値はそれに限定されるものではなく先に述べたように、値aは $0.1r_0$（0.1・N.A.）$\leqq a\leqq 0.4r_0$（0.4・N.A.）程度であればよく、値bについては $0.4r_0$（0.4・N.A.）$\leqq b<0.8r_0$（0.8・N.A.）程度であれば、本発明の効果を得ることができる。ただし、値bの上限は、半径rの値に対して$b<r$になっている必要がある。

【0046】図17は本発明の第2の実施例（図6）による遮光板8を用いたときの焦点深度特性のシミュレーション結果を示す。このとき遮光板8は図6に示した通り、十字状遮光部と中心円形遮光部とを組み合わせたもので、シミュレーション条件は露光波長λを0．365μm（i線）、投影光学系PLのウェハ側開口数N.A.を0．50、遮光板8の外周の輪帯状遮光部8Bの内径rをσ値（r/r_0）換算で0．7、十字状遮光部の幅の半値aを$0.28r_0$、長さの半値bを$0.56r_0$、そして中心円形遮光部の半径cを$0.46r_0$とした。図17のシミュレーション結果のように、斜めL&Sパターンの焦点深度特性DO3は、従来の通常の円形面光源（$\sigma=0.7$）での焦点深度特性DCに比べて格段に

改善されており、かつ、縦、横のL＆Sパターンに対する焦点深度特性ＤＶ３も十分に大きな値となっている。

【００４７】ここでのシミュレーションでは、中心円形遮光部の半径ｃの値を０．４６ｒ／σとしたが、これも前述の半値ａ、ｂ同様、０．４６ｒ／σに限定されるわけではなく、0.3r／σ（0.3・N.A.）＜ｃ＜0.6r／σ（0.6・N.A.）程度であれば本発明の効果を十分に得ることができる。ただし、半径ｃの値があまりにも小さいと、図６の遮光板８は図４の遮光板と同様の形状となるため、斜めパターンについての焦点深度の改善度はやや減少することになる。すなわち、図１７中の特性ＤＯ３が、図１６中の特性ＤＯ２のようになる。また、半径ｃの値があまり大きいと、それは輪帯照明（後述）に近づくため、縦横のL＆Sパターンに対する焦点深度特性ＤＶ３中で、パターンサイズが０．４５μｍ付近に見られるような焦点深度が特に大きくなる部分が存在しなくなり、やはり望ましくない。

【００４８】図１８は本発明の第３の実施例（図７）による遮光板８を用いたときのシミュレーション結果を示す。この場合のシミュレーション条件は、投影光学系の開口数 N.A. を０．５０、面光源の最大半径であるσ値（$r／r_0$）を０．８、十字遮光部８Ａの各寸法、半値ａ、半値ｂをそれぞれ０．２８r_0、０．５６r_0、そして周辺の微小遮光８Ｃ、８Ｄまでの距離ｄを０．６４r_0とした。この図１８のシミュレーション結果と、前述の図１６に示したシミュレーション結果とを比べると、図７の遮光板８を用いたときの斜めパターンについての焦点深度特性ＤＯ４は、図４の遮光板８を用いたときの焦点深度特性ＤＯ２（図１６）、又は図６の遮光板を用いたときの焦点深度特性ＤＯ３（図１７）と同程度に改善されていながら、縦横のL＆Sパターンのうち、特に０．４５μｍ程度のライン幅の中程度の微細度のパターンについても、焦点深度特性ＤＶ４の如く、焦点深度が改善されることがわかる。

【００４９】尚、図７の遮光板中の微小遮光部８Ｃ、８Ｄのエッジ距離ｄの値も、０．６４r_0に限定されるわけではなく、０．５r_0＜ｄ＜０．８r_0程度の範囲であればよい。ただし距離ｄがあまり小さいと縦横パターンに対する解像度が低下してしまうことになり、あまり大きいと効果が表れない。そこで図７に示した遮光板８の光軸近傍をさらに遮光する図６のような中心円形遮光部、あるいは四角形遮光部を追加してもよい。

【００５０】図１９は比較のために輪帯照明での同様のシミュレーション結果を示すものである。このときの条件は露光波長λを０．３６５μｍとし、そして０．７・N.A.（σ＝０．７）に相当する半径の円形面光源のうち、その半分の半径（σ＝０．３５）に相当する中心円形部を遮光部とした輪帯状面光源を考える。このような輪帯照明で得られるL＆Sパターンに対する焦点深度特性ＤＡでは、０．４２μｍ以上のライン（又はスペース）幅をもつ粗いパターンについて、幅でほぼ１．５μｍ程度の焦点深度が得られる。従来の円形面光源のときの焦点深度特性ＤＣでは１μｍもないのが実情である。ただし、実際のメモリーパターンの露光時を考えると、特に金属配線層の露光工程では大きな焦点深度が要求され、例えば６４ＭＤＲＡＭでは０．４５μｍ程度の線幅のL＆Sパターンに対して、幅で２μｍ以上の焦点深度が必要とされる。従って図１９の如く輪帯照明で得られる焦点深度特性ＤＡではこの要求を満たすことは難しい。また、上述の金属配線層の露光工程でも、特に焦点深度が必要とされているのは段差（１μｍ程度）部に形成されている縦、横のL＆Sパターンであるため、本発明のような変形光源形状はきわめて有効なものである。

【００５１】尚、実施例中においては、光源を水銀ランプとしてｉ線を用いるものとしたが、これは他の波長であってもレーザ等の光源であってもよい。またシミュレーションの条件では、投影光学系の開口数 N.A. を０．５とし、遮光板によって作られる最大の面光源の半径ｒをσ値で０．７、又は０．８としたが、開口数 N.A.、σ値はこれに限定されるものではない。ただしσ値については、０．７以上程度が効果的である。また光源形状の最外形は、遮光板８の輪帯遮光部８Ｂの内径エッジで規定される円（σ）によって制限されるものとしたが、その最外形は四角形、六角形等で規定してもよい。さらに各実施例中の遮光板８の遮光部形状はX方向、Ｙ方向に関して同形状（対称形）としたが、その形状はX方向とＹ方向とで異なってもよい。すなわち、各遮光部の寸法値ａ、ｂ、ｄ、あるいは中心に四角形遮光部を設けた場合の各エッジの中心からの距離ｃの値が、Ｘ方向とＹ方向とで異なってもよい。

【００５２】実際の照明系中では、フライアイレンズの射出面の光量分布はフライアイレンズの各エレメントレンズの配列に応じて離散的、すなわち点光源の離散的な集合となる。このとき、各エレメントレンズの断面形状が長方形であると、離散的な点光源のそれぞれの間隔もＸ、Ｙ方向で異なってくる。そこで実効的な照明条件（レチクルへの照明光の配向特性）をＸ、Ｙ方向で揃えるために、各遮光部の寸法値ａ、ｂ、ｃ、ｄの値をＸ、Ｙ方向で積極的に異ならせることが必要となることもある。また、本発明の各実施例で用いる遮光板８の各透過部８１ａ～８１ｄ、８１ｅ～８１ｈに対して効率よく照明光を集中させて光量損失を減らすために、遮光板８の前に、それらの透過部に照明光を集中させる集光手段（プリズム、ミラー、ファイバー等）を設けるとよい。さらに各実施例の遮光板８は透過部と遮光部より成るとしたが、遮光部の一部、または全てを半透過部（望ましくは透過率が５０％以下）としてもよい。また、露光を行う工程によって、必要な焦点深度や縦横パターンと斜めパターンの重要度が異なるため、それらに対応できる形状をもった複数の遮光板８を、図３のターレット１０

に用意し、交換使用可能としておくことが望ましい。シミュレーションにおいては、使用するレチクルを遮光部（クロム層）と透過部から成る通常のレチクルとしたが、本発明を、いわゆるハーフトーン位相シフト（遮光部の代わりに1～15％程度の透過率を持ち、かつ透過部を通る光との間の位相をπだけ異ならしめるハーフトーン透過部（薄膜）を設ける）方式のレチクルの投影時に用いると、本発明の効果をさらに高めることができる。

【0053】以上の各シミュレーション結果から明らかなように、縦横パターンPv、Phのウェハ上での線幅が、64M－DRAM製造時に使われる0．4～0．5μm程度のとき、各実施例に示した遮光板8は焦点深度の改善に良好に作用している。しかも、同時に斜めパターンTa、Tbについても焦点深度の改善効果が得られている。ただし縦横パターンと斜めパターンとで同じ線幅サイズでの焦点深度を比べてみると、確かに斜めパターンの方の焦点深度はそれ程大きくない。しかしながら、1枚のレチクル内での縦横パターンのピッチ（線幅サイズ）に対して、斜めパターンのピッチ（線幅サイズ）の方が1．2～1．5倍程度粗い場合、例えば図17中の縦横パターンに対する特性DV3中で線幅サイズが0．42μmのとき、斜めパターンの線幅サイズがその1．5倍（0．63μm）であると、斜めパターンに対する特性DO3中の線幅サイズ0．63μmでの焦点深度は2μm程度得られることになる。

【0054】ところで先の図9から明らかなように、対象とする縦横パターンのピッチに対して最適化された4つの光量重心点（0次光の重心点）80A～80Dが、投影光学系PLの瞳EP内で正方形の各角に位置するとき、対象とする斜めパターンのピッチが縦横パターンのピッチの約1．4倍程度である場合、斜めパターン用に補助的に加えられる照明光の光量重心点80Eは、理想的には2つの重心点80A、80Bを結ぶ線分とY軸との交点に一致する。

【0055】図20は、縦横パターンと斜めパターンとのピッチ関係とが上述のように約1．4倍になっているときに、ほぼ理想的な関係で各光量重心点を配置した様子を示す。この図20中で、瞳EPに分布する0次光、1次回折光は各重心点の回りに所定の大きさで広がりを持つものとする。その広がりの形（領域）は、本来、遮光板8の透明部81a～81d、81e～81h等の面光源の形状に一致するが、ここでは単に円形で表してある。

【0056】図20の場合、斜めパターン（45°、135°）から発生する4つの0次光（重心点80A～80D）の夫々に対応した1次回折光$-Dt_1$は、瞳EPのほぼ中心を重畳して通る。また、重心点80Eを0次光として通る斜めパターンからの1次回折光$-Dt_1'$は、斜めパターン用の補助光源の重心点80Hと80Fの夫々の近傍、又は一致した位置を通る。同時に、重心点80Eを0次光として通る横パターンからの1次回折光$-Dy_1$は、斜めパターン用の補助光源の重心点80Gの近傍、又は一致した位置を通る。

【0057】このような0次光、1次回折光の分布のうち、変形光源を用いたときの斜めパターンに対する焦点深度拡大効果を低減させる成分は、瞳EPの中心に現れる4つの1次回折光$-Dt_1$である。そこでこのような条件のときには、投影光学系の瞳EPの中央部のみに減光フィルター（NDフィルター）を配置し、4つの1次回折光$-Dt_1$の光量を適度に減衰させるとよい。

【0058】尚、図20中の縦横パターン用の4つの光量重心点80A～80Dを作る円形領域と、斜めパターン用の4つの光量重心点80E～80Hを作る小さな円形領域との配置関係は、そのまま照明系内に設ける変形光源用の遮光板8の透明部形状と相似になる。従って遮光板8として、図20中の4つの大きな円形領域と4つの小さな円形領域とを透明にした形状のものがそのまま使える。

【0059】

【発明の効果】以上のように本発明によれば、これまで変形光源で問題とされていた斜めパターンに対する結像性能、特に焦点深度改善度の劣化を防止することができ、また縦横パターンについても従来の変形光源とほぼ同様の性能を得ることができる。

【図面の簡単な説明】

【図1】本発明の基礎となる変形光源を持った照明系の斜視図。

【図2】本発明による変形光源の原理的な形状を示す図。

【図3】本発明の実施例としての投影露光装置の全体構成を示す図。

【図4】第1の実施例による変形光源用の遮光板の形状を示す図。

【図5】レチクル上のL＆Sパターンの周期方向の一例を示す図。

【図6】第2の実施例による変形光源用の遮光板の形状を示す図。

【図7】第3の実施例による変形光源用の遮光板の形状を示す図。

【図8】図7の遮光板の形状とフライアイレンズとの配置関係の一例を示す図。

【図9】各実施例に示した変形光源を用いたときの、投影光学系の瞳面での光束分布を模式的に示す図。

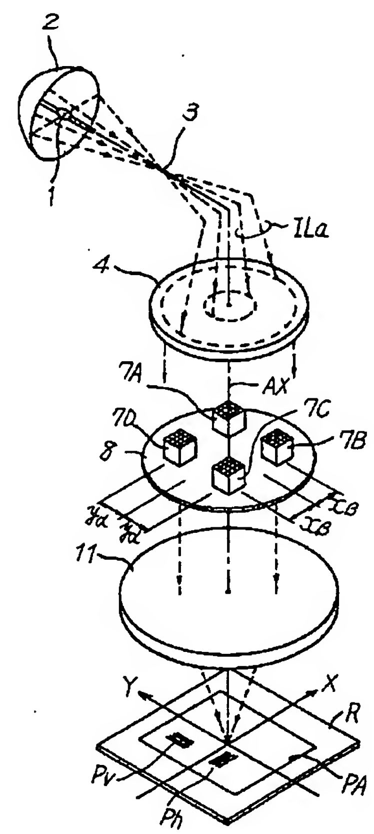
【図10】第4の実施例による照明系の一部の構成を示す図。

【図11】図10の照明系に好適な遮光板の形状を示す図。

【図12】第5の実施例による照明系の一部の構成を示す図。

【図１３】従来の変形光源用の遮光板の形状を示す図。
【図１４】従来の変形光源用の遮光板の形状を示す図。
【図１５】図１４の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１６】図4の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１７】図6の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１８】図7の遮光板を用いたときの焦点深度特性のシミュレーション結果を示すグラフ。
【図１９】輪帯照明を行ったときの焦点深度特性のシミュレーション結果を示すグラフ。
【図２０】本発明による変形光源を用いたときの投影光学系の瞳面での光束分布を模式的に示す図。
【符号の説明】
１・・・・水銀ランプ
７、７Ａ～７Ｆ、７０Ａ～７０Ｄ・・・・フライアイレンズ
７０Ｅ～７０Ｈ・・・・オプチカルファイバー先端
８・・・・遮光板
１１・・・・コンデンサーレンズ
Ｒ・・・・レチクル
ＰＬ・・・・投影光学系
Ｗ・・・・ウェハ

【図１】



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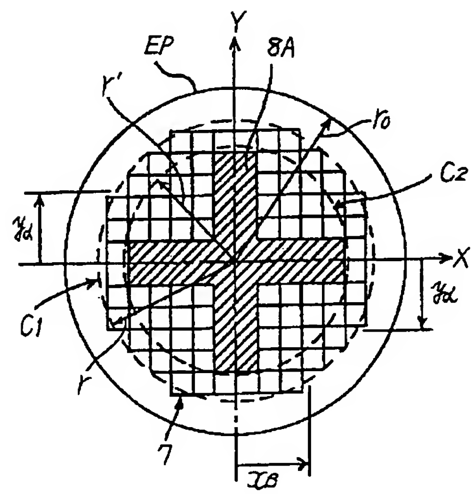
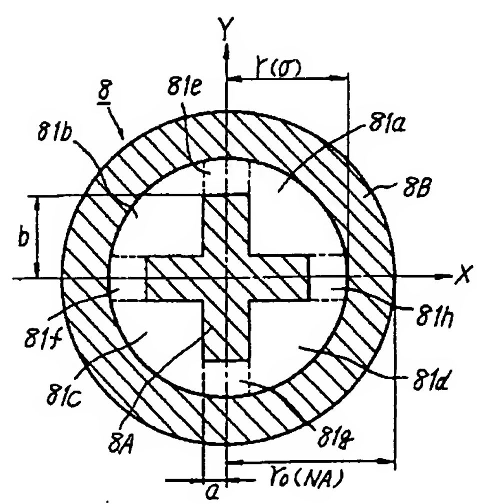


【図４】



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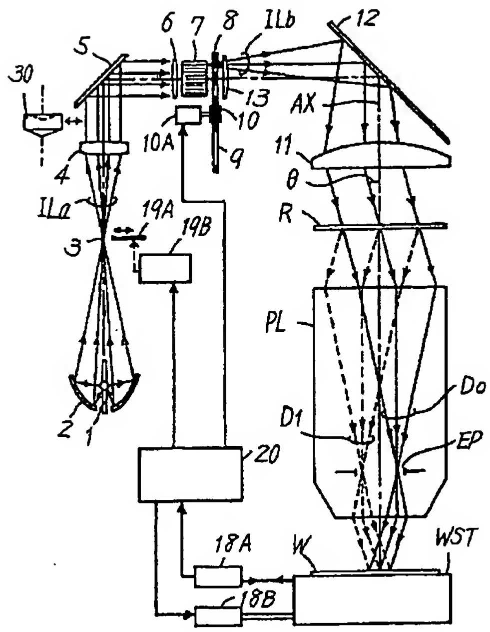

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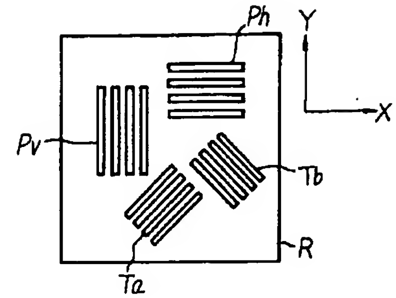

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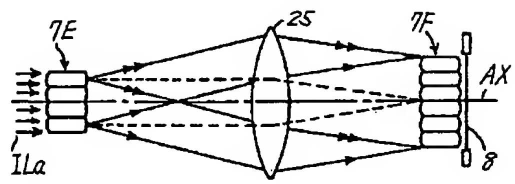

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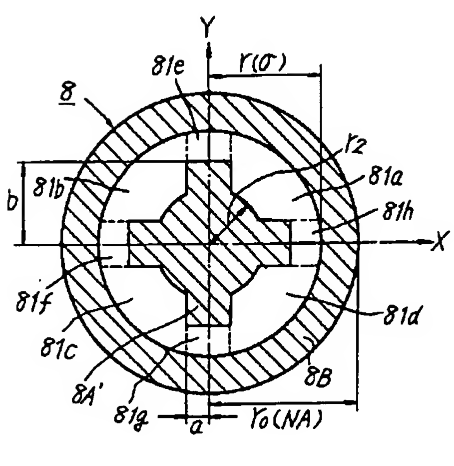

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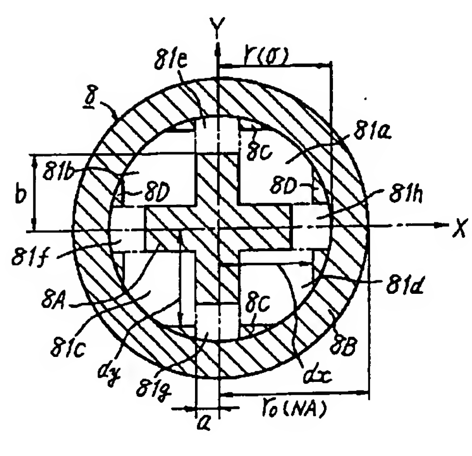

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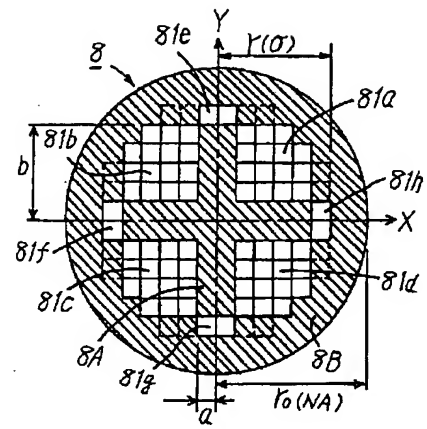

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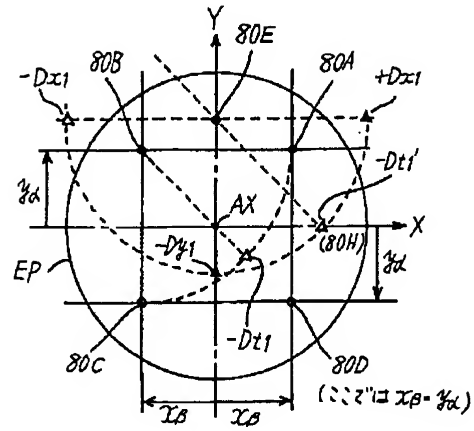

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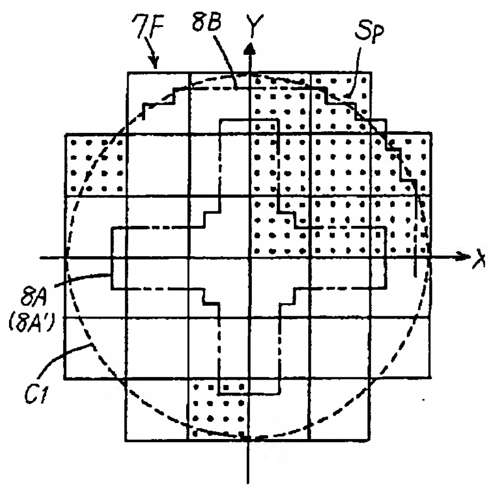

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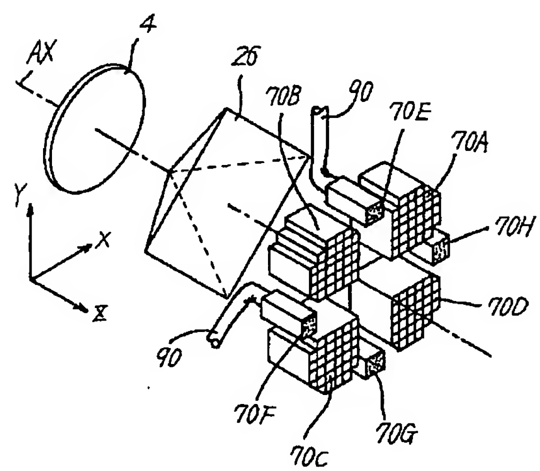

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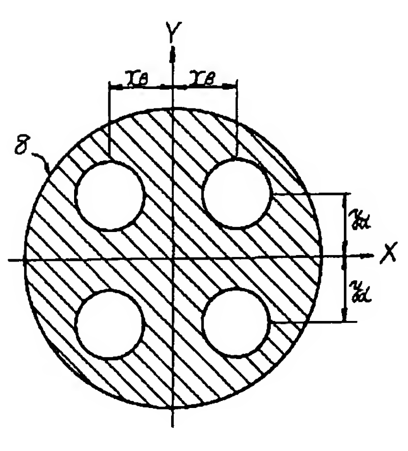

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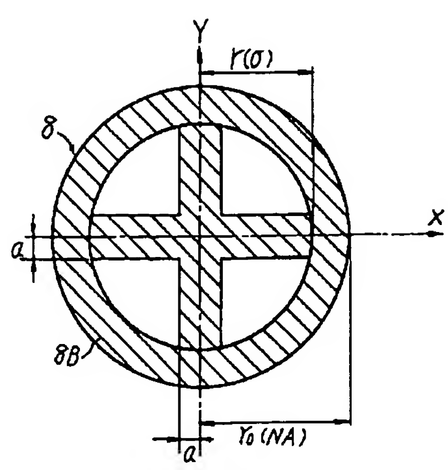

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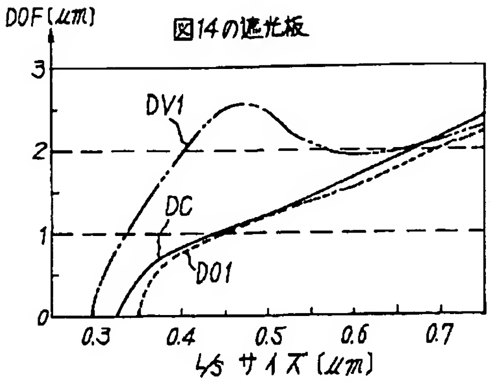

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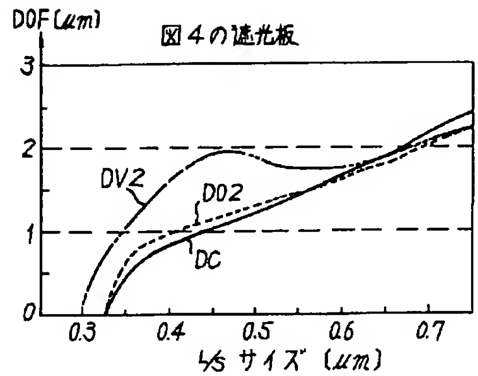

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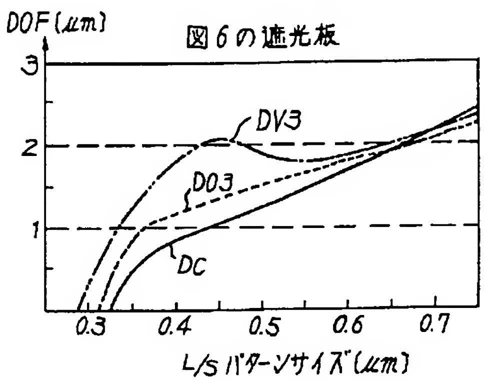

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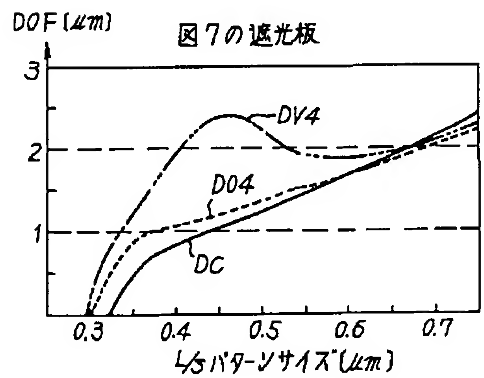

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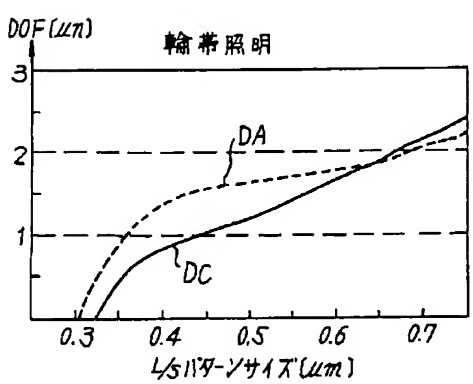

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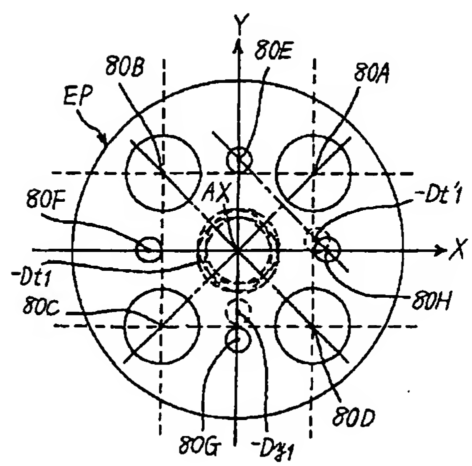

フロントページの続き

(51)Int.Cl.5	識別記号	庁内整理番号	F I	技術表示箇所
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